THE ELECTRICAL AGE

VOLUME XL

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NOTICE TO ADVERTISERS

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The Year

It has been the fashion to refer to 1908 as a year of depression. A close analysis of the year's records in those lines of activity which are of special interest to our readers does not exactly justify this. There is a wide difference between actual depression and non-expansion. We have been so used, since the beginning of the present century, to seeing a huge yearly growth of the various electrical industries that any failure to realize the rate of growth looks to us like an actual setback.

If we shift the point of view and look at 1908 as compared to preceding years, it must be said that the utmost that can be said against it is that it showed no appreciable growth. There are, however, exceptions to this, taken both ways. Certain traction systems have continued to show a substantial increase in traffic. Many telephone companies report the largest earnings in their history. On the other hand, the manufacturing interests really were set back, as would be natural under the conditions. But even these have shown a substantial upward movement throughout the year, particularly since the presidential election. It is doubtful if the tariff revision agitation, which has checked the growth of business in some lines of manufacturing will have any pronounced effect on the electrical manufacturing interests. It is unlikely that even with electrical machinery and appliances on the free list, the foreign manufacturer (who is principally German in this instance) would be able to seriously compete with the Americans in the home market. In cases where the ratings were on the same basis, American manufacturers have usually been able to meet foreigners in the markets of the world, so far as price is concerned.

In general, the year closed with a bright outlook for the resumption of expansion all along the line, and business in 1909 is, in most quarters, expected to be a record-breaker.

Turning to the technical and scientific fields, it is pleasing to note that in 1908 the advance, which business and industry lacked, has been, in general, fully maintained. In the oldest branch of electric work, the telegraph, the movement has been along the lines of improving the working capacity of the current by the introduction of the several approved forms of high-speed automatic instruments. Wireless telegraphy has continued to expand both in volume of business and in maximum distance covered. Regular communication by wireless across the Atlantic is now an accomplished fact. Perhaps the most important development of the year in this line is the discovery of a method of controlling the waves so that their energy may be confined to one direction instead of spreading out in a sphere. A strong movement is being made looking towards the reduction of cable rates by 60 or 75 per cent.

The technical progress in telephony has been mostly limited to the wireless branch. The latest experiments indicate successful communication over a distance of 300 miles. In ordinary telephone work some progress has been made in improvement of the currents, and the use of the automatic exchange has increased.

In electric railway work the rule "make haste slowly" has been observed. Many projects were held up because of financial stringency, and this has undoubtedly retarded technical progress. Some new single-phase roads have been placed in commission and a couple of heavy traction installations have been put to the test of practice. The effort to raise working direct-current voltages keeps up nobly, and the perfecting of the commutating pole traction motor promises much in this connection. In addition to the railway work being done in this country, the Prussian lines from Magdeburg to Leipsic, 80 miles, and a 22½-mile line from Leipsic to Halle, are being electrified.

In the field of transmission the signal events are the increases in commercial working voltages due principally to the tandem suspension type of insulator. For the first time commercial transmission has crossed the 100,000-volt limit. The transformer is as far ahead of the insulator as ever, and the next move seems to be the inventing of some insulator covering of the conductors, oleaginous or otherwise, which shall check the loss due to discharges.

In the central station industry the salient feature is the advent of the improved form of the tungsten lamp. While some fears have been expressed as to the immediate effect of this lamp on central station revenues, it appears that they are rather groundless, as the new business which comes from the improved lamp will, almost invariably, soon make up for any temporary loss. The tungsten lamp comes to hand just at the proper time to help out in the campaign against the gas lamp, and reports are that it is being used with good effect. The replacement of the unsanitary gas burner, either of the Welsbach or straight gas type, by the tungsten lamp where the latter is properly loaded ought to be an important factor in improving the public health. We do not think that the electric light salesman, as a rule, lays enough of stress on the deleterious effects of the gas lamp in lowering the tone of the lung tissues during the winter months, thereby rendering the user an easy victim to all sorts of "colds," and occasionally to pneumonia, to say nothing of tuberculosis.

The flaming arc lamp has come more and more to the front during the year, and seems now to be firmly established in popularity.

In the widening field of electrochemistry the two noticeable features are the gradual improvement of the processes for electrical steel making, and the improved results in getting atmospheric nitrogen in form for fertilizer. The first of these, the refining of steel, is one of great interest to everyone, and the fixation of nitrogen touches every member of the human race.

Great progress has been made both here and abroad in the perfecting of commercial processes. A steel plant

is going up in Switzerland that will eventually absorb 22,000 h.p. and produce 200 tons of fine steel in a day. The best evidence of the progress made is that the existing steel companies themselves are taking up the work. The electric smelting of iron ore in regions where it is suitable has also made noteworthy advances. Let it be noted in this connection that probably more than half of the known iron ore deposits of the world lie in these regions.

The processes for the separation of nitrogen have improved to such a point that plans are being made for a plant to be devoted to this purpose that will utilize 120,000 h.p., and it is said that even larger installations for this kind of work are contemplated.

In summing up, we think our readers will agree that 1908 has been a pretty good year and that it has bequeathed to 1909 a much better heritage than it received from its predecessors. We feel that the electrical industries have the best of reason to face the new year with energy and confidence. To all of our readers, present and prospective, we wish the fullest measure of prosperity and success, and pledge ourselves to do all in our power to cooperate with them to bring it on.

As heretofore, we shall continue our efforts to present the best and freshest news without fear or favor, and to merit the support and recognition so freely given us in the past.

Ratings of Generators and Motors

In the Standardization Rules of the American Institute of Electrical Engineers is found the following somewhat broad recommendation: "All electrical apparatus should be rated by output and not by input. Generators, transformers, etc., should be rated by electrical output; motors by mechanical output."

This method of rating is sanctioned by usage and convenience, but those who have had to incorporate it in their business transactions have long been aware that it has its disadvantage. The chief of these is the lack of definiteness. Just what is the output of a generator or motor? The answer that it is the amount of electrical or mechanical energy that can be taken therefrom without the accompanying rise in temperature exceeding a given limit at once brings up the point.

As is well known, such apparatus, in a broad sense, may be designated as "transformers" in that there is a transformation of mechanical to electrical energy, and *vice versa*. These transform with the loss of a fraction of the total energy that is transformed. Most of this lost energy, whose amount, relative to the total quantity of energy transformed is determined by the "efficiency" of the transforming device, appears as heat that is generated in the iron of the magnetic circuit, the copper of the electric circuit and in the bearings. Now, in so far as the capacity of the machine itself for producing "output" is concerned, it is this lost heat-energy that determines the permissible limits. In turn, the amount of heat-energy that can be permitted to develop in a given machine is determined by the rise in temperature that the machine can stand without permanent injury. As generators and motors are made "in the present state of the art," the substance in the machine that is most liable to permanent injury is the insulation. In reality, therefore, the rating of a machine, if based on its output, is determined by the heat-resisting quality of the insulation used therein.

Much trouble has resulted, and continues to arise, from the looseness of definition that is unavoidable in a chain of limits such as here exists, and much thought has been expended in trying to devise ways to simplify the question of rating. About the net result, so far, is that engineers have to make a more or less accurate guess at the critical permissible temperature that the insulation can stand, make another conjecture of approximately the same degree of accuracy as to the difference between that maximum temperature, which in the nature of the case always occurs in the inward parts of the machine, and a corresponding temperature in any external part that can be more or less accurately measured, and specify that the machine shall give its "rated" output without the measurable temperature exceeding the figure indicated in the second guess.

When it is considered that a dozen or more different factors enter in the determination of what the values above dealt with really are, such as the actual efficiency of the machine, its ventilating capabilities, its environment, the arrangement and nature of the insulation and the time-factor in its deterioration, as well as a number of other elements of lesser import, the difficulty of getting at once an approximate knowledge of the exact state of affairs is manifest.

As is usual, in such cases a compromise, born of experience and nurtured by custom, grows up and is accepted. So we find the Institute specifying divers permissible temperature rises for different sizes and kinds of machines and minute directions for measuring this permissible rise. Other and higher figures are specified for "overloads" which are limited as to time, and so the rating question stands to-day.

Now there is a considerable difference of opinion as to what the proper values of the temperature rise really are, and the engineer who tries to get away from the above-mentioned specifications and do some rating of his own, finds that this difference leads manufacturers to quote very differently both as to weight and costs on generators, and motors of the same rated output. Competition among the manufacturers leads to these results which are sometimes very misleading and gets both them and the engineers into trouble. In the foreign markets the difference between American and European practice in this respect has led to such a condition of affairs that exporting manufacturers have had to rerate their machines, calling a 10-h.p. motor in the United States a 15-h.p. one in Japan, a 25-h.p. machine acquiring 10 extra horse power in rating by shipping over the Rio Grande, and so forth.

When the average citizen hears about this practice without understanding its real cause, if he has free trade tendencies he notes it as another "protection outrage," and stores it up for ammunition in dealing with his Congressman. We fear that the electrical manufacturers will have this brought unpleasantly to their attention before the present tariff agitation is over.

The remedy, we would venture to suggest, lies in all the generator and motor manufacturers agreeing upon and adopting a standard set of temperature specifications—and sticking to them. With this done, the situation will be greatly simplified, and we believe that the consulting engineers will welcome it, as in the end it means the saving of trouble and misunderstanding for all concerned. This has been the universal result of movements looking to uniformity of action, and that "standardization" which is so severely criticized in some quarters will, we believe, in this case find few if any objections raised.

We are glad to note that some work has already been done in this direction, and hope to see it pushed ere long to a successful finish.

Valuation of Public Service Franchises

The synopsis of the decision of the Supreme Court of the United States concerning the right of the Consolidated Gas Company of New York to fix the charges for their service contains one feature that is of special interest to public service corporations and their stockholders. After deny-

ing the right of the Gas Company to charge more than the rate allowed by the act of the New York Legislature, until it has first proved that that rate is so low as not to permit of a fair return on the capital invested, which the court suggests is, in this particular case, six per cent., the decision inferentially promises that in the case it can do this it will have ground for petitioning that the act be nullified and a higher rate established.

This brings up the old question as to what is the legitimate capitalization of such a corporation. Like nearly all similar corporations in this fair land, the Gas Company is popularly supposed to be considerably over-capitalized. By the same token it is in close relationship with most of the electric light and power companies as well as the traction interests. Indeed, almost every company whose duty and privilege it has been to use the public streets is in the same situation. And in almost every case the elusive elements in footing up the capitalization are the "good will" and "franchise."

Considerable mental work had been done on the problem in this case under discussion. From a total of $90,000,000, claimed by the company, the figure had been cut to $60,000,000 by a lower court, the difference being mainly in the values assigned to the above-mentioned factors.

The Supreme Court disposes of "good will" with the statement—which looks sufficiently obvious to the lay mind—that the "good will" of a monopoly has no tangible value. It cannot be gainsaid that the average public service monopoly does not enjoy much "good will" from the great public it serves. If the "good will" of a concern is defined as the mental attitude of the body from which that concern draws its revenues, as compared with the attitude of the same body toward other similar concerns, this part of the case backs what our legal friends call a *locus standi,* and therefore the "good will" element vanishes from the discussion where a monopoly is concerned. The court holds that where there is no possibility of competition there can be no allowance for good will. As will be readily seen, this involves most of the large electric utilities of the great cities.

As to the valuation of the franchises, the situation is by no means so clear. Taxes on franchises are on many statute books and therefore they must have some tangible value. In the case in point the gas company originally valued its franchises at $24,000,000. The company's lawyers state that the decision sustains their value at $7,781,000, which is said to be the price paid for them when the consolidation took place. It would appear that franchises which did not cost their holder anything can have no capital value, and those that have been paid for have just that value—the inference being that any increase in the actual value of these franchises belongs to the public and not to the titular owner. If this is finally established, the future promotors of public utility companies will have so much less fat in the pot.

The equity of the case in general is not made any plainer by the fact that the Public Service Commission laws of New York forbids the capitalization of such franchises altogether. This, of course, applies only to the future, but if it were wrong and unjust in the past some way to remedy it should be devised. And this way should be a direct one and not the one advocated by many commentators on the case, which point out that if a corporation can arbitrarily place a swollen value on its franchises and call them "property," it can thus make extortionate charges on such a basis *and that the only way the public can help itself is by constructing parallel enterprises of its own.* It would be supposed that at this late day regulation instead of competition would be the dominant idea in this connection, but evidently the notion of the old crude and wasteful method, which works the greatest injury both to the corporation and the people, dies hard.

We believe that a satisfactory and equitable solution of this important and much-discussed problem will ultimately be found, and that it will be based on the principles laid down by French law in similar cases. To us, this appears to be another of the none-too-frequent instances in which "they do these things better in France."

Vacuum Cleaning Systems

During the past two years the market has been deluged with vacuum cleaning equipments. These machines have been in many forms, but all have sought to obtain the common object of removing floor dirt by sucking it up and depositing the collected results in a receptacle from which it is later removed.

The interiors of these machines have been made up of bellows, pistons, fan blades and impellers similar to those in a Root blower in general construction.

They may be classed into two general divisions: portable and non-portable. Portable sets are carried in the hand or may be wheeled about on a very small truck. In any event, the cleaning apparatus itself is carried from room to room and the cleaning tool attached by means of a few feet of hose. The motors operating these small sets take their current from a convenient light socket or are connected to a cleaner circuit, when the house has been wired for such.

The non-portable sets are mounted in the cellar with a good foundation under them. An iron suction pipe is run through the house, with outlets at one or more points on each floor so that the rubber hose and cleaning tool only have to be handled by the operator. Such an equipment is installed large enough to permit two or more cleaning tools to be at work at one time. It therefore follows that non-portable sets are generally of a substantial size.

The motors operating non-portable sets are made hand-starting or automatic-starting, as desired. When hand-starting the attendant must go down to the cellar and manipulate the rheostat before attempting to clean. The use of automatic starters allows the attendant to start and stop the motor from any floor by a push-button control. This latter system is the favorite one.

Engineers and others, who are called upon to recommend cleaner systems, find themselves at a loss to select with much assurance the good from the bad amongst so many. Of course, all cannot be good, nor are all competitors of a given outfit N. G. The first question always is the general mechanical one of rigidity or stability. When parts are light and seem to work hard against themselves on test, it is well to be cautious. Again, the cleaner end may have good bearings, easily operated valves, valves easy of repair and not liable to give trouble from dirt; the whole may be of simple construction, and yet the power may not be sufficient in the motor which drives it. On the experience of those who have tested and examined nearly every make on the market, nine out of every ten of the machines driven by motors so small as to come within the underwriters' requirements about attaching to lighting sockets are not worth substituting for a good broom and carpet cleaner. The makers of small equipments have to remove every bit of surplus weight which can be eliminated in portable sets, hence, motors lacking sufficient power. But the non-portable machines seldom err on this account, as a good large foundation must be built anyway and some extra weight does not make any difference. The test applied by responsible makers is that a vacuum tool must have suction effort enough to pick up ordinary BB lead-shot from the floor. The character of cleaning work done by a tool

capable of this need never be feared. Inferior cleaners may take up light surface dirt spread carefully over a floor, but will not do genuine cleaning. To pick up dirt from depressions, to get it out of somewhat inaccessible places, to pick up pins, tacks and the like, which will insist upon getting into carpets and rugs, requires the vacuum equal to the shot lifting pull.

The drift in the market at the present time, among those who have used one or more systems, is towards the non-portable type. The cost is much higher but the results justify the expense, if the building is of any size.

Most vacuum cleaner outfits have to deal with dry dirt. In large buildings it is often necessary to scrub a ballroom floor or tiled hall. The vacuum tool is then used to suck up the dirty water. It may interest our readers to know that scrubbing tools are now making their appearance, which will round out and complete the work to be done. By the use of these tools a stream of water containing soap or other cleaning substance will be carried into the scrubber. As the whirling brushes move over the floor a clean floor covered with dirty water will be left behind. The cleaner tool following will draw this up, leaving a clean, wholesome surface. Thus will the slow, painful hand labor of the well-known scrubwoman be superseded by rapid, easily handled machinery.

Recording Operating Costs

We invite the especial attention of our readers to the article in this issue describing the operation of the mechanical plant of the Hotel St. Regis.

In a subsequent article will be described an even more notable feature connected with this plant, the inception and development of the "Relief and Educational Society" of the Engineers' Department. It will later be understood how intimate is the connection between the splendid operating record of the plant and the admirable training school for engineers and firemen, which owes its existence to Mr. J. C. Jurgensen, chief engineer of the St. Regis' engineering plant and chief instructor in the technical course of the St. Regis "Relief and Educational Society."

In order to grasp the means which were at hand to accomplish the results shown, it is well to get a general idea of the plant itself. As is well known, the St. Regis is one of the most splendid hotels of the metropolis of the Western hemisphere, and the expenditure that was lavished on the architectural construction and equipment of the building was not stinted in the mechanical equipment. As will be seen, the plant is complete in every detail, and neither thought nor money was spared to secure the very best both for construction and operation.

The open shop and the nine-hour day are in full force, though the watches are eight hours, as elsewhere noted. Grading and promotion are strictly on merit, and every employe's record is carefully kept. The work of the "Educational Society," or the apprenticeship course, as it may otherwise be called, has been of great benefit to the operating and maintenance force, mostly all of which are members.

The record of the four years of operation of the St. Regis plant shows that these results were not obtained without infinite effort.

We present the following table to show how operating costs of power have been cut down:

Year	Total Operating Cost Boiler h.p.-hr.	kw.-hr.
	Cts.	Cts.
1905	.971	1.94
1906	.914	1.89
1907	.844	1.76
1908	.666	1.33

The operating costs of both the boiler horse power and the kilowatt-hour have been steadily reduced. The very noticeable reduction shown for the year just ended is attributed, principally, to two causes:

First, the improved working out of the bonus system which has now had time to get in its best effect.

Second, the improvement in the boiler performance caused by the adoption of the automatic ball-bearing turbine blowers.

The first and most important of these causes is intimately connected with the work of the training school, which will be described in a later issue.

The analysis of the cost record sheets reveals the completeness and accuracy with which the operating costs of this plant are kept. All details find their proper place, being compiled from the daily reports as they are turned in. The results of pains taken are evident. It would be hard to find any private plant where the records are more complete, and equally hard to find one where, under the given conditions, better economics are obtained.

It is interesting to note that with all the adverse conditions as to extra attendance, etc., as noted, the total estimated average cost of a kilowatt-hour at the switchboard is now estimated at about 1.5 cents per kilowatt-hour. Such cost figures do not make the work of the central station power solicitor the easiest thing in the world. And it is but fair to assume that there are numerous other plants of the same kind that can, and do, approximate these results. Where the operating records are kept with care it should be a simple matter to prove that such is the case.

The Chicago Electrical Show

The fourth exposition of the Chicago Electrical Trades Exposition Company promises to be even more successful than the preceding shows. The successful conduct of these shows, success that has attended in the past, demonstrates the actual necessity in the trade for expositions of this sort, when properly managed. The annual visit of thousands of operating engineers to view the new apparatus developed during the year is one of the invaluable trade opportunities to manufacturers, and they are not slow in appreciating the importance of putting their machinery on exhibition. There is nothing like seeing the apparatus itself. Advertisements in trade write-ups and circulars are more or less impotent as compared with the actual inspection of apparatus in operation, in so far as succeeding in arousing the attention of the trade and in creating a desire to use the apparatus. The purchase follows if new equipment becomes necessary for the economical operation of the plant.

The endeavor of the Chicago management to make this year's display as far as possible a working exhibit, is a step forward in developing a comprehensive and representative display of the electrical industry. The announcement that the United States government will display an entire equipment of machinery apparatus of a modern battleship is particularly noteworthy in directing the attention of the electrical fraternity to this field of endeavor. With the expanding needs of our navy and merchant marine, it promises to be very lucrative. The importance which now attaches to the electrical equipment of vessels may be understood from the fact that about one-tenth of the cost of modern battleships lies in the electrical machinery and equipment. The government has much to gain in inviting the attention of a multitude of engineers who will visit this display, and we have no doubt that an inspection of the equipment will result in many helpful suggestions.

The Model Operation of an Isolated Plant

A GREAT many modern isolated plants are often unable to give the costs of their operation for the reason that in, we may say, the majority of instances their costs are not accurately and systematically kept. It is, therefore, instructive to find an instance in which not only are the cost records most admirably kept, but the latest methods of improving the efficiency of the operating force have been applied with signal success. While there are many plants in which one or both of these features receive more or less attention, it would be hard to find one in which they are better thought out and more closely systematized, than in the mechanical plant of the Hotel St. Regis at 55th st. and Fifth ave., New York.

In this article will be set forth at some length the way in which this plant, which is a model in its way, is run, and also the methods of keeping track of the multitudinous details of the operation of such a plant, which is comparable with that of an ocean liner or a battleship.

The power plant is one of the most complete ever installed in a building of this character. It comprises a 1200-h.p. boiler outfit, 1000-kw. capacity of electric generators, a 100-ton refrigerating plant and a very extensive heating and auxiliary equipment. Most of these auxiliaries are steam driven so as to supply exhaust steam at low pressure to the heating, ventilating, hot water and water distilling plants. The plant is located in the sub-basement, some 50 ft. below the pavement, and is divided into a boiler room 40 x 50 ft., an engine room 72 x 100 ft., a fan room 40 x 50 ft., and rooms for workshop, storeroom, toilet and locker rooms for the employees. Although the boiler room represents only 2250 sq. ft. devoted to the actual power apparatus and the engine room 1800 sq. ft., which is a scant space for a 1000-kw. plant, yet owing to the compact arrangement and the use of vertical types of apparatus, wherever possible, satisfactory clearances for working about the plant have been secured in nearly all cases. This was done in part by double-decking the hydraulic elevators.

BOILERS AND AUXILIARIES.

The steam-generating equipment consists of four 300-h.p. Heine water-tube boilers, set in three batteries in the boiler room, which is at the rear of the sub-basement. They are arranged in three settings, one containing two units and the other two single boilers each. A seven-foot space is left at rear and sides for access to piping connections and cleaning doors. A 17-ft. firing floor extends in front of the boiler, which is paved with cast-iron floor-plates. Overhead is a six-inch I-beam runway for a hand-operated trolley hoist to convey coal from the storage bunker under the sidewalk

Fig. 1.—HOTEL ST. REGIS.

to the floor. Coal is handled in buckets of 500-lb. capacity and weighed in the bucket at the entrance of the boiler room. A two-foot steel fence holds the coal pile on the forward side and keeps clear passage way.

The boilers have each a 48-in. steam drum, 21 ft. long, with the Heine wrought-steel tube headers attached at either end, between which are fitted the tubes. Each unit has two hundred and three 3½-in. tubes, 18 ft. long, giving a heating surface of 3500 sq. ft. They are designed for 150 lb. steam pressure and are equipped with hand-fired furnaces having a grate area of 60 sq. ft. Although a 60-in. steel stack is carried above the roof-line of the building to a point 300 above the grates, thus giving a very good draft, the combustion is further improved by the installation at the rear end of a "Wing" automatic turbine blower, which runs at 3400 r.p.m. and serves to regulate the draft. These blowers are so light and portable that they can be shifted from boiler to boiler, and in a few minutes be set in place as the conditions may require.

The boiler-feed equipment consists of four 7½ x 5 x 6-in. duplex steam pumps, arranged with flexible connections for various combinations, but are usually returning condensed water from the receiving tanks of the heating system to the boilers. Each pump has a Kieley automatic pump-governor. Goubert vertical closed feed-water heaters are used for preheating, the heating surface amounting to 250 sq. ft., disposed in two-inch seamless brass tubing. From the heater the feed water passes through a wood combination filter and purifier and then through a Worthington hot-water meter. Supplementing the pumps are a pair of No. 6 Nathan injectors, which have suction connections to the city water mains. Each boiler is provided with blow-off connections leading to a blow-off tank, whence the blow-off water can be pumped up to the level of the street sewer. The pump for this service is automatically controlled and arrangements are made to recover a part of the heat of this water by passing feed water through the blow-off tank.

PIPING.

The steam-piping system comprises an arrangement of distributing headers for both live and exhaust steam, by means of which great flexibility of control is obtained. The high-pressure header in 20 in. in diameter by 13 ft. long and has two 10-in. supply connections and five delivery connections. The 10-in. boiler connections each serve two boilers by means of an eight-inch branch to each. These branches are fitted with gate and non-return stop valves. The delivery connections consist of a ten-inch main supplying the electric-generator units, a seven-inch connection to the refrigerating service, another seven-inch line through a pressure-reducing valve to the low-

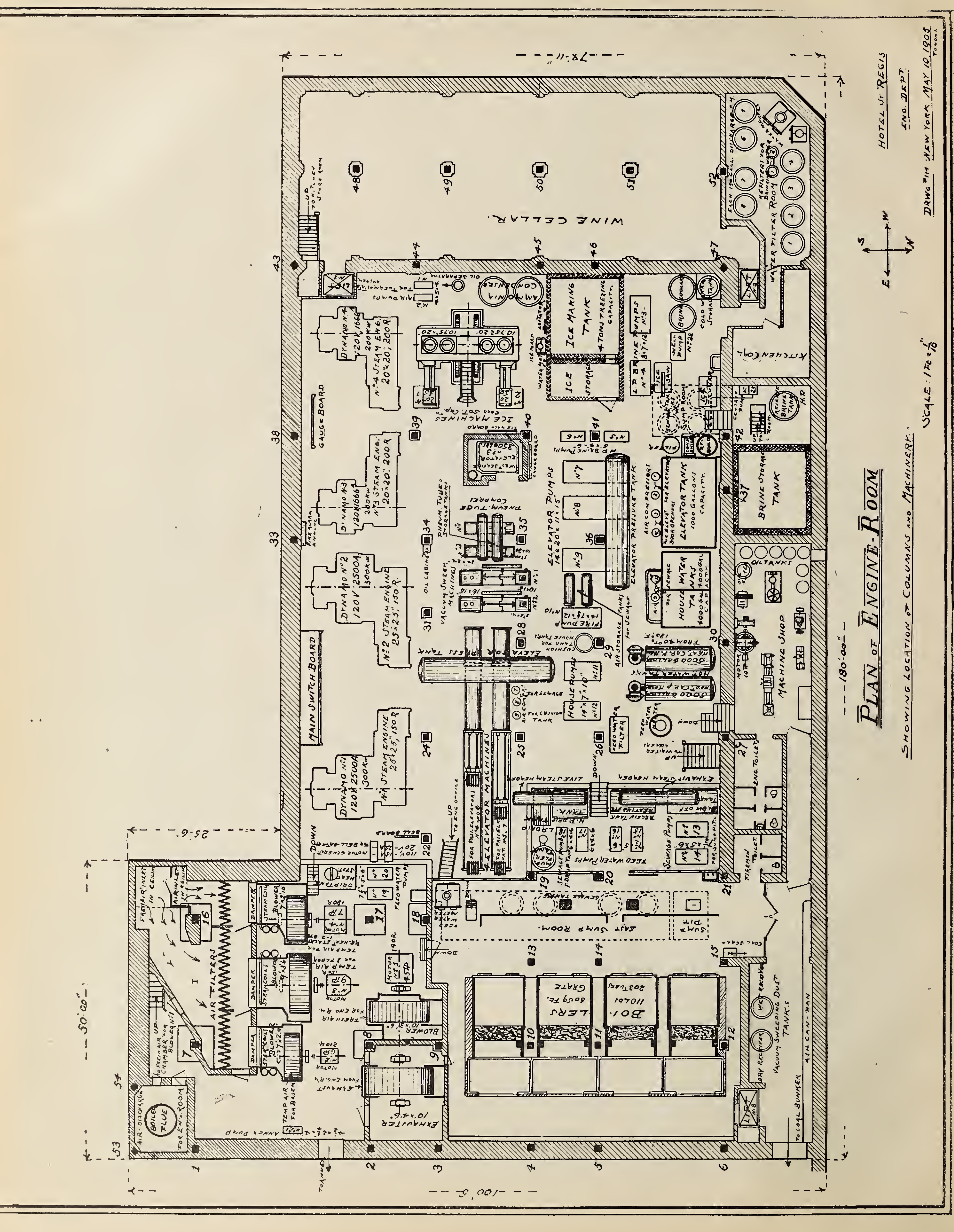

PLAN OF ENGINE-ROOM
SHOWING LOCATION OF COLUMNS AND MACHINERY
HOTEL ST REGIS
ENG. DEPT.
DRWG #114 NEW YORK MAY 10, 1905
SCALE: 1 Ft = 1/16"
WINE CELLAR
MAIN SWITCH BOARD
GAUGE BOARD
ICE MAKING TANK
BRINE STORAGE TANK
ELEVATOR PUMPS
HOUSE PUMPS
MACHINE SHOP
OIL TANKS
KITCHEN COAL
EAST SUMP ROOM
SUMP PIT
BOILERS
AIR FILTERS
EXHAUSTER
BOILER FLUE
ELEVATOR MACHINES
VACUUM SWEEPING DUST TANKS
ASH CAN RUN
COAL BUNKER
180'-00"
100'-5"
78'-11"
50'-00"
25'-6"

Fig. 2

pressure header to make up for the heating system, and two six-inch lines, one for the pumping machinery and the other for the general high-pressure steam service throughout the building.

The exhaust steam header is of cast iron 18 in. in diameter and 11 ft. long, with two supply and four delivery connections. The supply comprises a 16-in. connection to the muffler tank of the engine room exhaust-steam system and a seven-inch connection from the high-pressure header through the reducing valve, above noted, for making low-pressure steam to the heating system when the engine exhaust is insufficient. The exhaust header has an atmospheric relief for freeing it from excess pressure when steam is not used as fast as it is produced.

Delivery connection from the exhaust header consists of a 14-in. main, which runs to the upper floors for the heating stacks of the indirect heating system, a 10-in. line to the tempering coils in the fan-room, a six-inch line to the sub-basement relay heating stacks and a six-inch line to the tempering coils of a ventilating system. The main exhaust line from the engines delivers to the exhaust header through a Potter muffler tank, which is also connected with a Cochran grease extractor, and a 54-in. receiver, which is equipped with 24 quarter-inch galvanized screens and a coke filter to aid in the complete removal of oil from the exhaust.

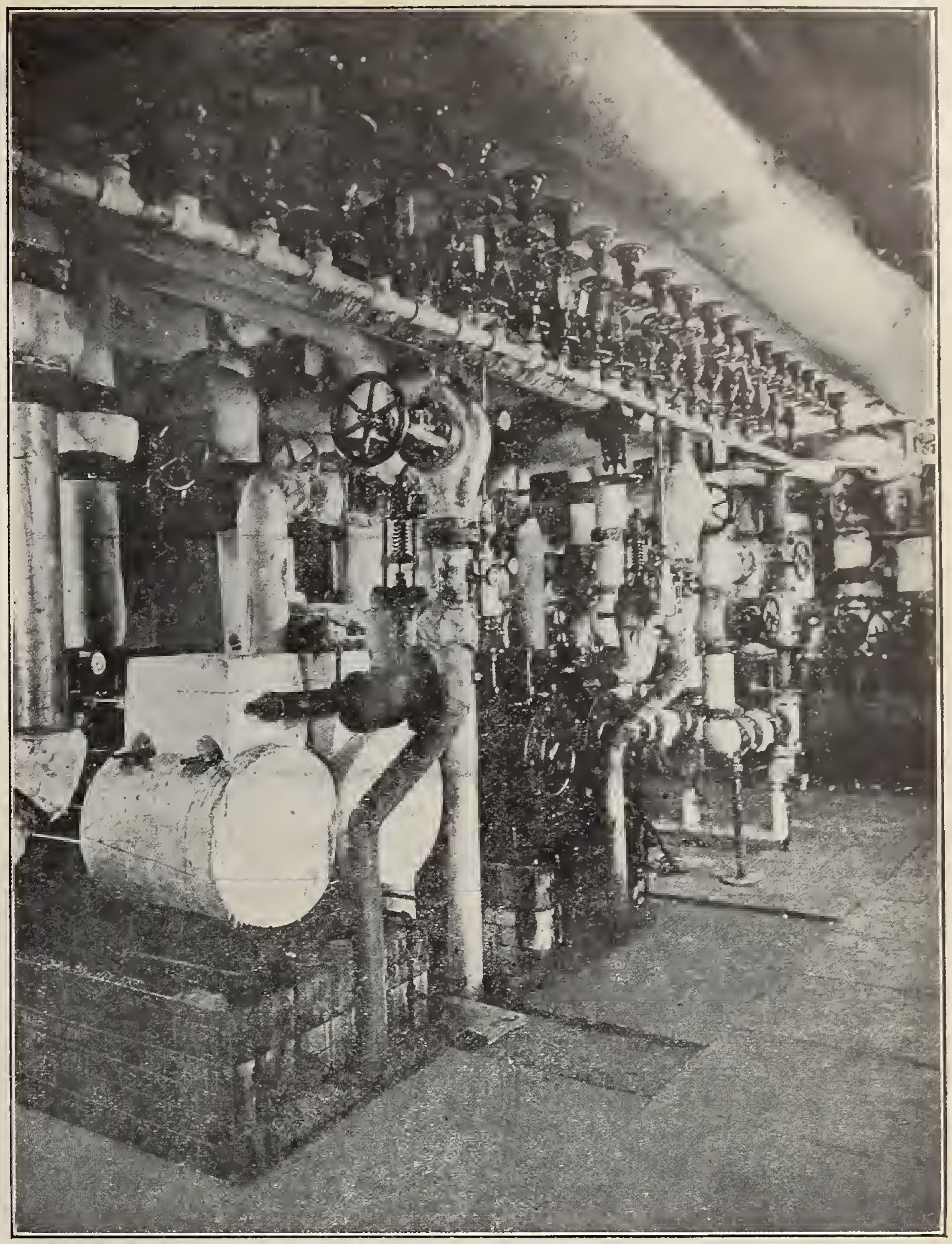


Fig. 3.—VIEW OF MACHINERY ROOM.

HEATING SYSTEM.

The heating system used in this building is the "indirect" type in which warm air pumped and filtered is heated by being drawn over heating stacks. There are three heating sets, one on the third, one on the seventh and one on the twelfth floors. Tempering coils which regulate the temperature of the air before it is admitted to the heating stacks are provided. The heating connections are all dripped through Kieley steam-stop connections to the low-pressure return tank. All mains are covered with Keasbey magnesia sectional fittings, canvas jacketed and banded.

ELECTRICAL PLANT.

The electrical generating plant consists of four direct-connected units, aggregating a capacity of 1000-kw. Two units consist of 25 x 25-in., 150-r.p.m., four-valve simple engine, direct connected to a 220-volt 300-kw. generator. The other two are 20 x 20-in., 200-r.p.m. engines of the same type connected to 200-kw. generators. The engines are all from the Harrisburg Foundry and Machine Co., and the generators from the Western Electric Co. The engines were installed under a guarantee of 24 lb. of dry steam per indicated horse power. The generators are all over-compounded four per cent. to insure uniform voltage with changes of load, and are guaranteed to stand 25 per cent. overload for three hours without undue heating.

The electrical distribution system is a two-wire one, all power and lighting feeders being kept separate and under separate control from the switchboard out. Blower motors for various purposes are wired to separate feeders, provided with independent switches and circuit-breakers placed on the main switchboard, so that they are at all times under the control of the operating engineer. The lighting is controlled through groups of three panelboards on each floor, which are supplied by separate feeders from the main switchboard.

The switchboard itself is a ten-panel white marble one with two panels for generator control, two for totalizing the output, one for light and one for power, and the remaining are three power-distribution panels and three for lighting distribution.

The equipment of the board includes Weston indicating instruments, Thompson recording meters for measuring the total output and I. T. E. circuit breakers. The entire electric light and power installation was made by the Western Electric Company, New York. The boiler plant and steam equipment, as well as the very complete heating and ventilating plants, were designed by Alfred R. Wolff, consulting engineer, New York. The electrical equipment was designed by Patterson Bros., electrical engineers, New York. Steamfitting was done by Gillis & Geoghegan, New York.

OPERATING DETAILS.

In starting to keep an accurate record of the operating expenses of this plant, it was realized that as less than half of the total output was converted

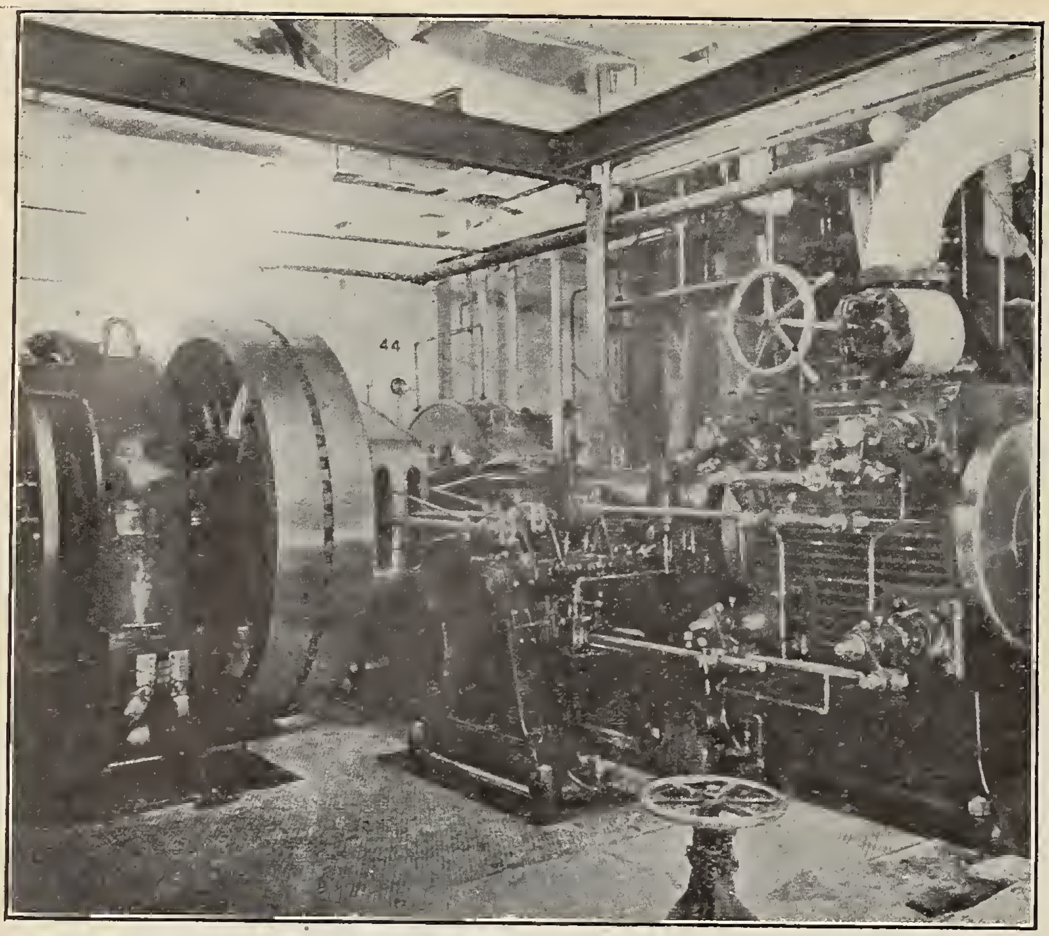


Fig. 4.—VIEW OF DYNAMO ROOM.

into electrical energy, some other basis than the kilowatt-hour must be used.

After due consideration the horse power hour from the boiler was decided on as the obvious point for measuring the output and the following routine was devised:

Coal is weighed on a section of the I-beam trolley runway at the entrance to the boiler room, and each weight is immediately entered on a pad provided. As a mixture of No. 2 and 3 buckwheat coal is used, as well as a systematic method of filling the bucket, an automatic counter on the trolley rail serves to check up the weight entries. These coal readings are used to check up the weekly inventory of coal on hand; the water is measured by a pair of Worthington turbine hot-water meters, as mentioned above, which meter is calibrated every week. Hourly readings of this meter are taken. The make-up water from the city mains varies greatly with the fluctuation in the amount of water returned from the heating system and from the numerous domestic uses in the hotel. The forms on which these readings are entered are somewhat as indicated below.

This quantity of water and coal represents the consumption during the eight hours of the watch, and from it, as a base, the horse power output of the plant is calculated. Allowance is made for the degree of moisture in the coal. The boiler-room crew's jurisdiction ceases at the high-pressure steam header.

Weight of Coal				Hourly Reading of Feed Water Meter			Remarks
					Reading	Cubic feet used	
536	530	518	515	12 P. M.	3255652	306	
538	552	525	523	11 "	5346	364	
537	536	520	529	10 "	4982	360	
543	538	522	517	9 "	4622	468	
528	531	525	545	8 "	4154	387	
533	540	526	543	7 "	3767	478	
541	536	528	515	6 "	3286	456	
520	526	524	517	5 "	2833	336	
532	578	525	517	4 "	2497	...	
542	540	527	...				
6125	5357	5242	3745				

Total coal, 20,469 lbs. Total water, 3,155 cu. ft.

Fig. 5.—FORM OF FUEL AND WATER CONSUMPTION LOG.

The watches in this plant are of nine hours each. The duty in engine and boiler rooms is eight hours. Thus the watches overlap each other by an hour, and as each watch's record is kept with equal care they have ample time to check up each other, and thus avoid the weakness incident to a system where one watch comes on reluctantly as the other goes off in a hurry.

The boiler-room force numbers seven. A head fireman, who does the boiler cleaning and repairs, and three watches, each consisting of a fireman and coal passer, make up the complement. The bonus system is in force, and the splendid results attained by its use will be dwelt upon later. The form of the bonus used here is as follows: A standard determined by years of experience is adopted. In this plant it is now four pounds of coal per boiler horse power hour. Each fireman does his best to save coal by coming below the standard. He is credited with a proportional amount, which is over and above his fixed wages. The bonus for the head fireman and coal passers is based on the total result of the efforts of the three watches. This arrangement insures the force against the bad effects of too much teamwork and keeps the three watches working as a unit.

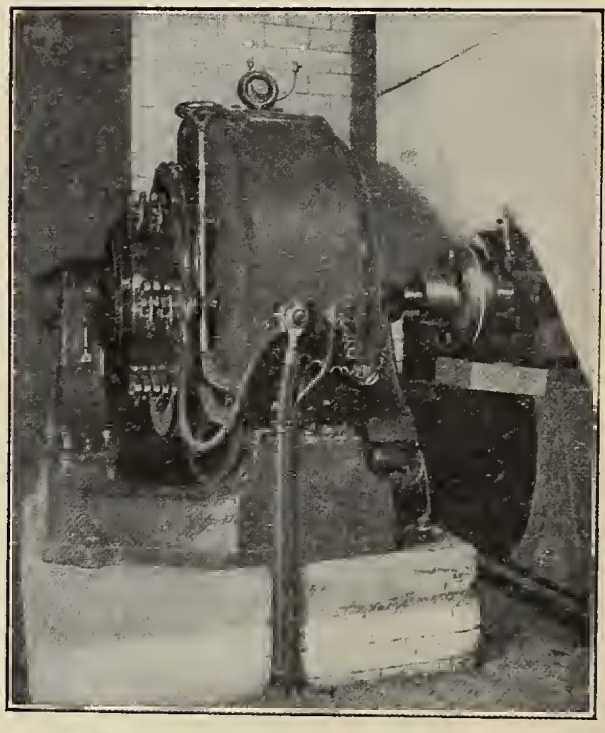


Fig. 6.—C. & C. ELECTRIC FAN MOTOR.

The outgoing watch presents its report as shown in Fig. 7.

The results of these fuel and water measurements are tabulated as shown in the following sheets.

The report here shown is for the last month of 1908, and gives the daily horse power developed for every day in the month, as well as all other routine features of the plant.

This table shows the fireman's bonus sheet as worked out for the

same month. In this particular boiler-room the scale of wages is as follows:

Head fireman......... $70
Firemen 65
Coal passers........... 40

man, amounting to over 18 per cent. in the case of the head fireman, and nearly 15 per cent. in the case of the most skilful fireman.

The engine-room force looks after the running of all the machinery, and ten men are employed in this work. The bonus system is not, as yet, employed in this division, but a scheme to take advantage of its benefits is under contemplation. In addition to this there are 15 men employed in "maintenance," which includes looking after the larger plant comprising the house utilities such as heating system, elevators, etc., and consists mainly of machinists, plumbers and their helpers. In all, the mechanical department employs a total of 36 people, of whom four only are charged to supervision. These include the chief engineer, his assistant, a combination bookkeeper, stenographer and typewriter and the storekeeper. The addition of this staff to the regular boiler- and engine-room force should be considered in the inspection the total cost per kilowatt-hour.

The report on gas meter and water from outside service is shown in Fig. 10. It will be noted that these readings are itemized so that each can be charged off to its proper division of the service.

From the above data, the total horse power evaporated is known, and all the routine elements in the cost of producing it are also known. The material cost of repairs is taken care of by the three sheets. One of these, Fig. 11, is for routine repairs and renewals; the other two, Figs. 12 and 13, are for recording the total cost of

BOILER ROOM REPORT.

Date *Jan 7-09* Time of Reading, 12 P. M. Watch No. 3.

BOILERS	1	2	3	4	5	TEMP FIRE ROOM		COND. OF COAL		KIND OF COAL
Boiler Pressure		115	115	115		Coal Fired Lbs.	20469	Dry		No 2 Buck.
No of Cocks of Water		2	2	2		Temp. Feed Water	210	Medium		mixed with
Time Tubes Cleaned						Reading Feed Water Meter	3355652	Wet	X	No 3 Buck.
Time Fires Cleaned		11^00	10^30	10^00		Draft in Inches in Chimney	1/10	Good		
Time Fires Banked						Temp. Chimney Gas	360°	Medium	X	
Cans Ash Removed from Back Connection						Cans Ash Removed	23	Bad		
Counter Reading 4 P. M.	56530					Counter Reading 12 P. M.	56568	Buckets Used	38	

The above readings to be taken by watch going ON in presence of watch going OFF and BEFORE same is RELIEVED

REMARKS: ______________________

O. K. ______________________
Engineer.

Fig. 7.—FORM OF DAILY BOILER ROOM REPORT.

All reports are made and signed by the head fireman, and the result of the crew's vigilance is seen in the handsome bonuses received by each

Hotel St. Regis.
Engineer's Dept. *General Boiler Report*

Month of *December* 1908

DATE	Coal burned in Lbs	Sq Ft of Grate surface	Lbs of coal per sq ft per hr	Cubic feet of Water evaporated	Average Feed Water Temp	Average Steam Press Lbs	Lbs. of Water Evaporated at aver temp	Ratio of Water to Coal	To Coal at 212°	From & at	Boiler H.P. developed	Lbs. of Coal pr H.P.	Lbs. of Ashes removed	% Ashes	Chimney Temp
1	53500	180	12.46	7781	211	115	465000	8.69	9.05	11.34	14115	3.81	10200	20.1	358
2	53500	〃	12.62	8044	211	〃	480900	8.81	9.20	11.56	14585	3.75	11100	22.51	363
3	55000	〃	12.94	8757	214	〃	523300	9.48	9.86	12.22	15740	3.52	10500	18.86	358
4	54100	〃	12.61	8328	215	〃	496600	9.15	9.51	11.88	14995	3.62	10800	19.94	360
5	50100	〃	11.60	8079	214	〃	482300	9.65	10.05	12.13	14550	3.44	8850	17.52	352
6	47800	〃	10.74	7684	216	〃	458800	9.63	10.02	12.22	13735	3.48	8400	17.46	347
7	54400	〃	12.59	7866	215	〃	469500	8.83	9.20	11.32	14215	3.76	10500	18.88	357
8	56100	〃	13.22	8595	211	〃	514000	9.06	9.44	11.71	15590	3.66	11250	19.37	358
9	54400	〃	12.59	8733	213	〃	521700	9.60	10.01	12.53	15775	3.52	10050	18.55	358
10	51800	〃	12.00	8394	213	〃	503800	9.57	10.14	12.12	15235	3.4	8400	16.31	353
11	5320[illegible]	〃	12.32	8524	212	〃	499000	9.32	9.71	11.81	15110	3.52	9450	17.54	355
12	50800	〃	12.10	8015	211	〃	479200	9.25	9.86	11.52	14510	3.57	8400	16.65	355
13	48500	〃	11.49	7418	213	〃	443500	9.20	9.59	11.37	13355	3.62	7650	15.74	357
14	52300	〃	12.11	7976	212	〃	476200	9.07	9.46	11.54	14405	3.63	7450	16.30	355
15	53500	〃	12.62	8228	211	〃	491900	9.20	9.61	11.34	14755	3.65	9000	17.30	357
16	52800	〃	12.73	7986	211	〃	477500	9.05	9.45	11.68	14485	3.65	9150	17.49	355
17	55600	〃	12.67	8176	211	〃	490500	8.83	9.22	11.32	14875	3.73	10800	19.49	357
18	56600	〃	13.10	8261	212	〃	496700	8.79	9.49	11.58	15035	3.77	11700	20.4	355
19	52500	〃	12.22	8079	213	〃	483400	9.08	9.53	11.83	14605	3.62	10050	19.37	352
20	47600	〃	11.02	7300	214	〃	435800	9.16	9.54	11.49	13150	3.62	8100	17.23	343
21	52000	〃	12.06	8208	213	〃	489900	9.68	9.84	11.92	14790	3.51	9150	17.44	357
22	53600	〃	12.41	8344	214	〃	500700	9.34	9.29	11.54	14995	3.57	8550	15.[illegible]	357
23	52100	〃	12.06	8308	213	〃	496200	9.51	9.54	11.31	15020	3.48	9950	14.98	347
24	56000	〃	13.91	8528	212	〃	507900	9.10	9.48	11.42	15360	3.64	10750	16.90	353
25	53400	〃	12.0[illegible]	7689	212	〃	459700	8.78	9.15	11.45	13900	3.76	10500	19.79	343
26	52600	〃	12.17	8012	211	〃	478800	9.12	9.52	11.83	14485	3.63	9150	17.46	350
27	50100	〃	11.59	7173	212	〃	428500	8.56	8.92	10.76	12955	3.87	8550	17.16	330
28	52900	〃	12.24	7998	211	〃	478300	9.03	9.42	11.35	14430	3.60	8550	16.25	342
29	50800	〃	11.75	7845	212	〃	468800	9.16	9.54	11.49	14175	3.62	8530	16.87	347
30	51900	〃	12.01	8120	212	〃	485300	9.31	9.69	11.38	14670	3.57	7650	14.70	357
31	50400	〃	11.66	8100	211	〃	484200	9.59	9.57	11.63	14650	3.46	7050	14.26	350
TOTAL	1629900			250549			14966900				452290		292800		
DAILY AV	52577	180	12.17	8082	212.4	115	482803	9.18	9.56	11.64	14590	3.61	9445	17.71	

Fig. 8.—GENERAL BOILER ROOM REPORT.

Hotel St. Regis,
Engineer's Dept. *Firemen's Bonus Sheet*

Month of *December* 1908 Coal Standard: 4.10 Lbs pr H.P.
Ash " : 17%

DATE	Boiler H.P. developed	Lbs of coal pr H.P.	% Ash	Lbs. of coal saved	Bonus earned	Boiler H.P. developed	Lbs of coal pr H.P.	% Ash	Lbs. of coal saved	Bonus earned	Boiler H.P. developed	Lbs of coal pr H.P.	% Ash	Lbs. of coal saved	Bonus earned
1	3390	3.93	20.30	576		5075	3.75	19.25	1776		5650	3.76	20.50	1920	
2	3545	3.84	22.08	922		5350	3.67	17.60	2300		5690	3.75	21.65	1990	
3	3690	3.66	17.78	1624		5725	3.41	17.70	3950		6325	3.44	21.16	3924	
4	3675	3.73	19.70	1360		5760	3.58	18.40	2962		5620	3.56	21.72	3035	
5	3870	3.31	16.43	2670		5400	3.47	16.05	3400		5280	3.53	20.30	3010	
6	3700	3.49	16.30	2258		4655	3.48	17.58	2882		5380	3.48	18.46	3335	
7	4925	4.38	21.5			3890	3.32	16.30	3032		5400	3.49	18.15	2310	
8	5975	3.65	20.16	2690		3965	3.59	16.90	2025		5650	3.74	22.02	2032	
9	5900	3.55	17.13	3245		4075	3.49	19.40	2485		5800	3.33	19.42	4460	
10	5710	3.39	13.92	4054		4150	3.42	16.90	2820		5375	3.39	18.12	3845	
11	5680	3.54	17.90	3180		3430	3.76	15.72	-1166		6000	3.37	19.60	4380	
12	5450	3.51	15.71	3217		3820	3.49	16.41	2330		5240	3.52	17.30	3040	
13	5100	3.65	16.30	2295		3640	3.58	13.85	1892		4615	3.62	17.06	2215	
14	5400	3.67	18.37	2320		5500	3.53	16.22	3135		3505	3.77	20.30	1086	
15	5275	3.58	16.68	2741		5975	3.59	17.90	3050		3505	3.77	17.03	1159	
16	5250	3.64	16.50	2415		5750	3.64	17.24	2643		3485	3.68	18.74	1465	
17	5245	3.85	18.57	1311		5900	3.73	19.75	2182		3720	3.62	20.15	1785	
18	5600	3.77	20.61	1848		5745	3.76	19.44	1953		3690	3.77	22.76	1217	
19	5355	3.56	19.62	2891		5300	3.46	16.58	3520		3750	3.84	21.90	976	
20	4350	3.58	15.38	2262		5355	3.64	17.70	2463		3445	3.63	18.[illegible]	1619	
21	3710	3.45	16.42	2411		5355	3.55	17.33	2945		5725	3.53	18.57	3263	
22	3790	3.48	14.62	2349		5265	3.87	16.15	1210		5940	3.37	16.50	4336	
23	3775	3.57	14.07	2000		5415	3.46	12.88	3465		5830	3.42	16.04	3968	
24	3910	3.58	13.42	2033		5570	3.56	15.15	3007		5880	3.77	21.64	1940	
25	3495	3.86	18.75	768		5105	3.66	19.25	2246		5300	3.75	21.38	1855	
26	3740	3.58	16.05	2019		5140	3.74	16.43	1850		5605	3.59	17.91	2858	
27	3300	3.85	17.72	825		4520	3.92	16.12	813		5135	3.84	17.51	1335	
28	5685	3.59	16.12	2899		3335	3.72	16.92	1267		5460	3.50	15.70	3276	
29	5350	3.51	14.36	3156		3445	3.86	17.00	825		5380	3.48	19.25	3335	
30	5485	3.47	15.03	3455		3750	3.71	14.02	1463		5435	3.50	15.02	3261	
31	5765	3.41	13.00	3991		3535	3.54	14.46	1979		5330	3.44	15.38	3250	
TOTAL	145110			69785	$7.87	149035			73036	$8.23	158145			81350	$9.18
DAILY AV.	4681	3.63	17.20	2251		4808	3.61	16.19	2356		5101	3.60	19.09	2624	

Head Fireman Bonus $12.64
3 Coalpassers each. 4 21

Fig. 9.—FIREMEN'S BONUS SHEET.

repairs, the requisition for material and labor are combined on the sheet, copies of which go to the engineer so that he may keep posted on the progress of the work.

Fig. 14 shows a card for keeping the storekeeper's record. This is in the usual form of a card catalogue, and is a complete history of the transaction.

Fig. 15 shows the report for the heating and ventilation systems.

The next figures indicate the reports for the laundry, refrigerating and elevator plants, respectively.

HOTEL ST. REGIS, Engineer's Department

METER READING.

Date

WATER METERS		8 A. M.	4 P. M.	12 P. M.
200846	Read'g	20998	21742	22914
8 INCH MAIN	Used	306	212	210
200324	Read	38846	39717	40210
48 INCH MAIN	Used	4009	4220	4821
200336	Read	8894	8997	9028
18 INCH MAIN	Used	900	127	18
TOTAL CUBIC FEET WATER USED				

MANUFACTURER'S No. OF METER	HOUSE No.		SUPPLIES	READING	AMT CUBIC FT
236596	GAS METERS	1	Gas Logs	35576	440
367691		2	1st and 2nd Floors Public Rooms	2184	721
639134		3	1st to 17th Floors, Guests' Rooms	2788	1472
667140		4	Kitchen Cooking	25572	2118
676-63		5	Halls, Corridors Servants' Quarters	22441	397
671677		6	Taking E. & W. Pantries E. & W. Mezzanine Bars	8648	10
847721		7	Kitchen, East	71774	771
468418		8	Sub-basement	18972	12
684726		9	Annex and Laundry	341	12
TOTAL CUBIC FEET GAS USED					4953

REMARKS:

SIGNED

Fig. 10.—FORM FOR GAS AND OUTSIDE WATER-METER READINGS.

HOTEL ST. REGIS

ENGINEER'S DEPT

No. 374 Date Dec 24 1908

STOREROOM REQUISITION

FOR ROUTINE WORK ONLY

Do not use this requisition on JOB NUMBERS. Do not ask for more material than is required

Quality	ARTICLES	Charge to	Cost Dols	Cts
	7 lbs waste	Refrigerating Plant		01
	Four 4 x 2 x 12 in. brushes	Generator # 2		72
		Cost of material		73

Approved by Engineer

Delivered to

Fig. 11.—STOREROOM REQUISITION FOR ROUTINE SUPPLIES.

The oil consumption is taken care of by the oiler's report, as shown in Fig. 19.

With the aid of the above-described system of reports, which will be recognized as based on marine practice, the records of the operating cost covering water, gas, oil, waste, renewals and repairs, can be accurately kept.

MATERIAL ORDER

HOTEL ST. REGIS

Engineer's Dept.

JOB No. 29078 TIME REC'D BY ENG.

TIME ORD. BY ENG.

GIVEN TO R. [illegible]

CHARGE TO [illegible]

HAVE THE FOLLOWING WORK ATTENDED TO.

[illegible]

Generator #4

ORDERED BY PER

REQUISITION FOR MATERIAL ON ABOVE JOB

ARTICLES	TAKEN	RETURN	USED
4 lbs sheet brass			
4 [illegible] brass rivets #7			

COST OF MATERIAL $0.42

" " LABOR 0.44

TOTAL COST 86

STORE KEEPER

Fig. 12.—MATERIAL REQUISITION FOR REPAIRS.

The charges for all elements of the operating costs are to hand, with the exception of those for attendance and office expenses.

These costs are grouped as follows:

Executive end Office Force........	4
Operating Force..................	17
Maintenance......................	15
Elevator Operators...............	7

The sum of this account keeping is shown in the cost record sheets, which are tabulated and presented below.

In analyzing the results which are shown on this sheet, it is well to remember that the purchasing and storekeeping are done by the mechanical department, and that there is a certain amount of house-service which is unavoidably charged against

HOTEL ST. REGIS

Engineer's Dept.

JOB No. 29078 TIME REC'D BY ENG.

TIME ORD. BY ENG.

GIVEN TO R Murray

CHARGE TO Engine room repairs

HAVE THE FOLLOWING WORK ATTENDED TO.

Make a new brushholder for

Generator #[illegible]

ORDERED BY PER

REMARKS

STATE WHAT WAS WRONG AND WHAT WAS DONE BY YOU ON ABOVE JOB.

a new holder had to be made

I turned it all out

TOTAL TIME USED ON ABOVE JOB. HOURS 2 MINUTES

TIME FINISHED

WORK DONE BY

Fig. 13.—RECORD OF LABOR AND MATERIAL FOR REPAIRS.

the plant in spite of the above-noticed efforts to regulate them. This makes the results obtained still more remarkable, and in the opinion of the operating engineer, the bonus system in the firing room is the greatest single factor involved in getting them. This system is further supplemented by the effects of the training given in the Society, and there is no doubt that the efficiency of the operating personnel in this plant is extremely high.

For | Cost Base Unit | Section | Shelf | Card No.

No. or Size | Make | Style | ARTICLE | MAX. | MIN.

DATE	RECEIVED							DELIVERED							
	Order No.	UNITS	FROM WHOM	List Price	Dis-count	Cost per Unit	AMOUNT	Req. No.	Job. No.	UNITS	Machine No. or Where	CHARGED TO	Cost per Unit	AMOUNT
TOTALS														

Fig. 14.—SAMPLE OF STOREKEEPER'S RECORD CARD.

HOTEL ST. REGIS.

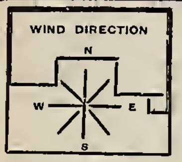
Engineer's Department

HEATING AND VENTILATING MOTORS

Date Dec. 13 Time of readings________

Motor No.	Location	Supplying	Rev. per min.	Temperature Record. Therm	Temperature Regular Therm	Number of Valves Open	Remarks
2	Sub Base.	Kitchen and Mezzanine floor	225	101	101	1	
3	Sub Base.	1st Floor					
4	Sub Base	Re-heating Stacks					
7	East Mez. Floor	Public Rooms 2d Floor					
8	3rd Floor	4th to 7th Floors Included					
9	7th Floor	8th to 12th Floors Included					
10	12th Floor	13th to 17th Floors Included					

Exhaust Motors				Kind of Weather			
11	18 Fl East	Fire Places, East		Sunshine	X	High Wind	X
12	18 Fl East	3-18 Floor East		Rain		Medium Wind	
13	18 Fl West	Kitchen		Cloudy		Light Wind	
14	18 Fl West	Fire Places, West		Outside temperature 42 Fh.			
15	18 Fl West	3-18 Floor West		Outside humidity____Per Cent			
				Back pressure____ ____Lbs			



SIGNED________

Fig. 15.—HEATING AND VENTILATING SYSTEM REPORT.

HOTEL ST. REGIS, Engineer's Department.

ELEVATOR REPORT

Date________

Elevator	Valve Cups Renewed: Operating	Valve Cups Renewed: Pilot	Packing: Piston	Packing: Piston Rod	Packing: Valve Stem	Oiled: Governors	Oiled: Operating Sheaves	Oiled: Operating Valve	Oiled: Cut-off Valve	Guides: Cylinder	Guides: Cross Head	Guides: Main	Guides: Travelling Sheaves	Inspected: Governors	Inspected: Cut-off Valves	Inspected: Top Sheaves	Inspected: Safety Planks	Candle Cups Filled Sheaves: Main	Candle Cups Filled Sheaves: Travelling	Candle Cups Filled Sheaves: Governor	Cars Running	Plunger Lifts: Lift	Plunger Lifts: Packed	Plunger Lifts: Valve Cups Renewed	Plunger Lifts: Guides Oiled	Plunger Lifts: Rod Oiled	Plunger Lifts: Lifts Running
3																						1					
4																						2					
5																						8					
6																						10					
7																											
9																											

Remarks:

Signed________ O. K.________ Engineer.

Fig. 17.—REFRIGERATING SYSTEM REPORT.

The total costs charged against the mechanical department are grouped as follows:

I Coal,	Boiler Plant
II Oil,	Engines
III Grease,	Heating and Ventilation]
IV Waste,	Refrigeration
V Water,	Electric System
VI Gas,	Elevators
VII Ash Removal,	Dumb Waiters
Attendance and Superv'n	Plumbing
Mechanical Stores,	Tool Equipment
Alterations,	Oiling System
Repairs,	Auxiliary Machinery
Improvements,	Sundrie

The mechanical department also takes care of the related mechanical branches of the house service.

They are:

Lighting
Laundry
Bars
Kitchens
Public Rooms
Guest Rooms
Alterations
Repairs
Improvement

The costs of all these branches of the service are entered up against the operating costs of the mechanical department.

Among the many special features that make the operation of this plant of exceptional interest must be men-

HOTEL ST. REGIS, Engineer's Department

ICE MACHINE REPORT.

Date________ 12 P. M. to 8 A. M. WATCH No. 1.

Hours	Mach. 1	Mach. 2	Pressures: Steam	Ammonia H. P.	Ammonia B. P.	Ammonia Car B. P.	Temperature of Condenser Water: In	Out	Brine Coolers Number 1	Number 2	Temperature In	Temperature Out	Temperature of Brine Returns: H. P.	L. P.	Ice Cream Box	Ice Cream Freezer	Brine Pumps Number 3	4	5	6	Pressure H. P.	Pressure L. P.	Av. Strokes Pr. Min. H. P.	Av. Strokes Pr. Min. L. P.	Engine Room Temperature	Freezing Tank Temperature	Cakes Ice Pulled
A. M. 1																											
2																											
3																											
4																											
5																											
6																											
7																											
8																											

	State of Meter	Cubic Feet Used	Spec. Gravity	Oil Used		Engine No.	Started
Water			Sodium Chloride	Cyl.	Qts.	" No.	Stopped
Ammonia			Calcium "	Eng.	"	" No.	Started
Brine				Liq. Base		" No	Stopped
Rev of Eng. No. 1			Street Water Presrure	5th Ave.	Total Time Run.	Hours	Mins.
Rev of Eng. No. 2				55th St.			

REMARKS:

O. K.________ Engineer

Fig. 16.—LAUNDRY REPORT.

Form 226 3000-1-27-06 HOTEL ST REGIS

ENGINEER'S DEPARTMENT.

Date,........ 190.

Daily Laundry Report.

Examined and Oiled Following Machines ...Motors 2 and 4...

Renewed Oil in .... all machines ....

Cleaned Following Machines .... Wringer ....

Shortened Following Belts ....

Packed Following Machines and Places ....

Special Work ....

General Condition of Machines and Shafting ....

NEW OIL USED.

Engine......16.......qts.

Cylinder ....qts. Signed.........

Fig. 18.—ELEVATOR REPORT.

tioned the "Plan Book." With the object of facilitating the quick and certain location of any of the piping connections, valves, fittings and other parts of the various systems, a book was prepared which shows on a reduced scale the floor plans of the hotel, indicating the locations of the above parts. The speedy location of any point is facilitated by a system of column numbers, which are the same as the constructive numbers. This high-pressure steam for general purposes, low-pressure steam, drip lines, scheme is especially convenient in the crowded basement and sub-basement.

Accompanying this set of floor diagrams is a series of schedules for all the systems of piping used, including hot and cold-water supply, lines for refrigeration, vacuum-cleaning system water piping and all other equipments and fittings in which is listed the location of each part with relation to the columns as well as the sizes of the pipes. Wherever possible the columns have their numbers plainly lettered on them, so that reference to the schedule is made easy to follow. These diagrams and schedules are on blue-printed forms, 9 x 12 in., a size convenient for the attendants to handle in using them. It is found that this book is frequently consulted not only in the locating of concealed pipes, but in identifying the pipes in congested parts. The value of this simple scheme is especially noticeable in the case of a new workman, who can by its use at once familiarize himself with the entire complicated plant and piping systems.

HOTEL ST. REGIS, Engineer's Department.

OILERS' REPORT.

Date__________ WATCH No. 1

Hours	Dynamo No. 1		Dynamo No. 2		Dynamo No. 3		Dynamo No. 4		Battery		Motor Gen.	
	Amp	Volts	Amp	Volts	Amp	Volts	Amp.	Volts	1 Amp	2 Amp.	1 Volts	2 Volts
1 A. M.												
2												
3												
4												
5												
6												
7												
8												

Temperature of Engine Room	State of Watt Meter at 8 A. M.					
	Power			Light		
	Engine	Cylinder	Liquid Base	Kerosene	Filt. Eng.	Filt. Cyl.
Oil Put in Tank Gal.						
Oil Used On Engine Only In Qts.						
Total Oil Used In Inches						
Total Oil Used In Gals.						
Depth Of Oil In Tank, Inches						

REMARKS.

____

O. K. __________ Engineer.

Fig. 19.—OILER'S REPORT.

Hotel St. Regis, Engineer's Dept. Boiler Room Economy Sheet

Month of November 1908

DATE		Total for the month	Average per day	
1	Weight of Coal as fired	1546500	51550	
2	Total Ash & Refuse	277800	9260	
3	Percentage of Ash & Refuse in Coal.	17.96	17.96	
4	Cubic feet of Water fed to Boilers.	225511	7517	
5	Total Weight of Water actually evaporated.	13459600	448653	
6	Factor of Evaporation.	1.0444	1.0444	
7	Equival. Water Evapor. from & at 212°.	14051885	468394	
8	Coal per Sq-ft. of Grate per Hour.	11.93	11.93	
9	Average Steam Pressure Lbs.	115	115	
10	" Temp. of Feed Water.	210.7	210.7	
11	" " " Escaping Gases °Fahr.	354	354	
12	Horse Power developed.	408635	13621	
13	Lbs. of Water evaporated per lb of coal, actual.	8.70	8.70	
14	" " " " " " " f. & at 212°	9.08	9.08	
15	" " " " " " " Combustible.	11.08	11.08	
16	Lbs. of Coal per H.P.	3.78	3.78	
17	" " Combustible per H.P.	3.10	3.10	
18	Cost of Coal per net Ton.	$ 2.455	2.455	
19	" " " consumed.	1897.09	63.23	
20	" " Maintenance of Boilers.	59.52	1.98	
21	" " Ash Removal	94.10	3.14	
22	Wages for Men on Boiler Plant. {Wages—$481.35 Bonus—$30.88	512.23	17.08	
23	Total Expenses for Boiler Plant.	2562.94	85.43	
24	Aver. " " per day.		$85.43	
25				
26	Actual Cost per Boiler Hp-hour at Header	Cents .6272		
27				
28				
29				
30				
31				
TOTAL				
DAILY AV.				

Hotel St. Regis, Engineer's Dept. Generating Plant Economy Sheet

Month of November 1908

DATE		Total for the month	Average per day.	
1	Total Kilowatts generated	131150	4372	
2	Watts produced per I.H.P.	605.0		
3	I.H.P. developed.	216777	7226	
4	Steam Consumption per I.H.P.	30.15		
5	Boiler H.P. used for Gen. Plant	197070	6569	
6	Coal used for Gen. Plant in lbs.	744925	24831	
7	" " per Kilowatt Hour in lbs.	5.68		
8	Cost of Boiler H.P. used. $	1236.02	41.20	
9	" " Maintenance of Gen. Plant.	5.79	0.19	
10	" " Oil, Grease & Waste.	4.98	0.16	
11	Wages for Men on Gen. Plant	418.17	13.94	
12	Total Expenses for " "	1664.96	55.50	
13	Average " per day.	55.50		
14				
15	Cost per Kilowatt-Hour Cents.	1.27		
16				
17	% of total Boiler H.P. used for Gen. Plant.	47.85		
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
31				
TOTAL				
DAILY AV.				

Fig. 20.—OPERATING COST RECORD SHEET.

Underground Lines

Cable Work

H. B. GEAR and P. F. WILLIAMS

Commonwealth Edison Co., Chicago,

THE conditions of American practice have been such that the draw-in system has been more economical in the long run than systems which require excavations to be made when alterations or repairs are needed.

The growth of the use of electricity in American cities proceeds at such a rate that cables must be reinforced or new cables added every year, and in the larger cities almost every day. If it were necessary to open up paving for all such work the expense would be very great and the time required would be greatly increased. Furthermore in streets which are recently paved, the ability to secure permits for such work is often very difficult, owing to objections on the part of abutting property owners who paid for the paving.

The chief disadvantage of the draw-in system is that more ducts must be laid down than are required for immediate use, and there is necessarily a portion of the investment which is unused for a few years, but which involves fixed charges. The value of the duct is, however, not usually more than half that of the cable, and in low tension systems not over 20 per cent, so that with a reserve capacity of 50 per cent. in a duct line, only from 15 to 25 per cent. of the total investment is idle.

The draw-in cable and conduit method of installing underground conductors has therefore become standard in American cities for transmission and distribution purposes, except that Edison tube or its equivalent is used for small lines in low tension distribution.

The type of cable used in American practice varies according to the service in which it is to be used. All cable drawn into conduit, however, is alike in that its insulation is protected by a sheathing of lead, which excludes all moisture and insures its permanence.

The earliest cables were insulated with rubber. The expense of this and the use of a waterproof sheath suggested the use of a wrapping of strips of oiled paper. The paper insulation proved very practical provided proper precautions were taken in making joints and in protecting the ends to exclude moisture. The difficulty of doing this under certain circumstances led to the development of insulation made of varnished cambric. This is less expensive than rubber but more expensive than paper, and is not so susceptible to moisture at joints and terminals.

These various considerations have resulted in the use of rubber insulation where frequent taps are made on distributing mains, but not generally for through lines such as feeders and transmission lines. Varnished cambric has been used to a limited extent in place of rubber, under similar conditions. It is also used quite generally in high tension bus-bar work inside of stations and substations. Oiled paper is used almost exclusively for feeders and transmission lines and can be used for primary distributing mains if the joints are covered with a lead sleeve and the ends are protected by potheads.

Fig. 1

Cables are made up in single, duplex, concentric, three-conductor and four-conductor or higher in special cases. Duplex is the term applied to two conductors which are enclosed in one lead sheath side by side, while concentric cable is made up with one conductor in the center and the other outside, as shown in Fig. 1.

In general, single-conductor cable is used when frequent taps are required as in distributing mains and concentric and other multiple conductor cables are used for through lines where taps are not made. Duplex cable has been used quite extensively in series arc systems and in single-phase taps of alternating current systems. It is difficult to train in manholes, as it does not bend easily in the plane of the conductors and with paper insulation is especially susceptible to the entrance of moisture and to injury from bending at too small a radius. Where it is used for distributing lines, rubber insulation should be used. Duplex cable is somewhat less expensive in first cost than two single conductors with the same insulation.

Concentric cables are used in preference to duplex where the conductors are over 4/0, as the side by side arrangement makes a cable which it is very difficult to bend, and in the larger sizes it cannot be drawn into a standard duct. The greater facility of jointing makes the use of duplex somewhat preferable in the sizes below No. 0 B. & S. The concentric arrangement is therefore employed for large low tension feeders and for two-wire primary feeders in some cases. This arrangement is especially advantageous with low tension feeders as it permits the use of a single duct for the outers of an Edison feeder of 750,000 or larger, where two ducts would be required if single-conductor cable were used. This is of much importance where feeders are numerous and duct space limited as in the case of some of the larger cities.

Low tension feeders which are added in a congested district are often run so close to other feeder ends that no additional neutral capacity is required. A concentric cable may thus constitute an entire feeder occupying but a single duct.

When additional neutral capacity is needed it may be installed in the form of bare stranded cable, one duct being used for the neutral of several feeders. Low tension distributing mains which have three conductors of the same size should preferably be of single-conductor cable, in order to facilitate the work of making service taps. This work must be done with the lines alive and is much more easily accomplished when one polarity may be dealt with at a time. The same is true of service cables which are terminated in damp basements or sidewalk areas where good insulation is maintained with difficulty and where the separation of polarities is very desirable.

Two-phase and three-phase feeders from which few taps are taken are preferably of three or four conductor paper cables, owing to the lower cost of a single lead sheathing and of paper as compared with single-conductor cables of cambric or rubber. The use of single-conductor on the primary mains is preferable from the standpoint of the expense of jointing, and separation of polarities. It is also desirable to use single-conductor cables at points where multiple-conductor feeders are connected to an overhead section as this makes a safer installation to handle on a pole top.

Secondary cables carrying loads of 200 amperes and upward are subject to inductive action when made single-conductor. The magnetic field may become strong enough to induce an appreciable difference of potential between the lead sheaths of single-conductor cables of a cir-

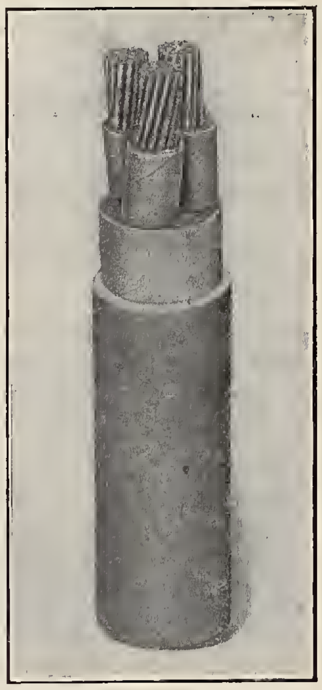


Fig. 2

cuit and cause a flow of current sufficient to cause injury to the lead sheaths while they are in contact with each other. This can be prevented with such cables by the use of a jute covering over the lead sheath, though this is found objectionable in case repairs are necessary owing to the tendency of such cables to stick in the duct. The preferable method with 0000 cables and smaller sizes is to use three-conductor cable. Short pieces of single conductor may be spliced in at the manholes where service taps are to be made or service taps may be made through a small junction box. The saving in cost of cable, due to the use of the three-conductor, compensates partly for the expense of making the extra splices.

Transmission lines which are usually three-phase are almost universally of three-conductor cable with a thickness of insulation on each conductor sufficient for the voltage between phases. Another layer is placed over all three conductors in addition to that on the separate cables as shown in Fig. 2 to provide insulation to ground.

The thickness of insulation required varies with the voltage for which the cable is intended.

Low-tension cables are provided with about 4/32-inch insulation between conductor and lead in single-conductor and the same amount over each conductor in a multiple-conductor cable, with no extra layer of insulation over all. This is the least which it is advisable to use for mechanical reasons and is sufficient for any voltage up to 500 or 600. In single-conductor cables of 350,000 to 1,000,000 cm. it is customary to provide 5/32-inch paper and 6/32-inch in larger cables, to provide proper strength of insulation during installation. Six-thirty-seconds-inch is found sufficient for 2000 to 6000-volt single-conductor cables up to 4/0, while 10/32-inch is required for potentials from 9000 to 13,000 volts.

The thickness of insulation, weight of copper, paper and lead sheath and over all diameters of various sizes of single-conductor paper insulated cables are given in Table 3. It will be noted that the diameter of 600,000 cm. cable being 1.462-inch, this is the maximum size of cable of which two can be drawn into a 3½-inch tile duct without undue strain. The diameter of three-conductor cables of varous thicknesses of insulation is given in Table 4. The largest diameter in each column is the largest cable which can be drawn into a standard tile duct.

The insulation provided in various cables designed for different voltages in some of the large transmission systems is shown in Table 4A. It will be noted that the thickness of insulation varies from 67 mils per 1000 volts between conductors at 6600 volts to 22 mils at 25,000 and from 52 mils per 1000 volts between conductor and ground, at 6600 volts to 16 mils at 25,000 volts. These differences are due in part to differences of opinion as to what factor of safety should be used in the design of high potential cables. The lower

WEIGHTS AND DIAMETER OF SINGLE CONDUCTOR, PAPER AND LEAD COVERED CABLE.

Size—B. & S. & Edison.	Thickness Paper.	DIAMETER IN INCHES, OVER			WEIGHTS IN LBS., PER FOOT.			
		Copper.	Paper.	Lead. 4-32 in.	Copper.	Paper.	Total, Copper, Paper, Lead. Lead. 3-32 in.	Lead 4-32 in.
14	3-32	.073	.260	....	.014	.0301	....	....
12	3-32	.092	.279	.530	.022	.0333	.599	....
10	3-32	.116	.303	.554	.135	.0378	.642	....
8	3-32	.147	.334	.585	.057	.0434	.724	....
6	4-32	.180	.430	.680	.085	.0735	.922	....
5	4-32	.209	.459	.709	.112	.0805	.999	....
4	4-32	.234	.484	.734	.140	.0865	1.069	....
3	4-32	.263	.513	.763	.178	.0935	1.157	....
2	4-32	.295	.545	.795	.224	.1012	1.256	....
1	4-32	.325	.575	.825	.255	.1085	1.338	1.722
0	4-32	.378	.628	.878	.338	.1213	1.511	1.920
00	4-32	.425	.675	.925	.426	.1326	1.681	2.111
000	4-32	.475	.725	.975	.532	.1447	1.871	2.326
0000	4-32	.524	.774	1.024	.650	.1565	2.072	2.551
200	4-32	.505	.755	1.005	.614	.1519	2.003	2.473
250	4-32	.568	.818	1.068	.790	.1671	....	2.786
300	5-32	.637	.949	1.199	.949	.2113	....	3.243
350	5-32	.680	.992	1.242	1.092	.2249	....	3.484
400	5-32	.735	1.047	1.297	1.224	.2397	....	3.738
450	5-32	.777	1.089	1.339	1.343	.2510	....	3.949
500	5-32	.820	1.132	1.382	1.550	.2625	....	4.251
600	5-32	.900	1.212	1.462	1.874	.2841	....	4.752
750	5-32	1.020	1.332	1.582	2.331	.3163	....	5.473
800	5-32	1.037	1.349	1.599	2.462	.3209	....	5.642
900	5-32	1.096	1.408	1.658	2.815	.3368	....	6.126
1000	5-32	1.157	1.469	1.719	3.138	.3532	....	6.583
1250	5-32	1.296	1.608	1.858	3.831	.3906	....	7.584
1500	6-32	1.412	1.787	2.037	4.681	.5786	....	8.969
2000	6-32	1.652	2.027	2.277	6.237	.6653	....	11.077
2500	7-32	1.848	2.285	2.535	7.674	.8716	....	13.221

Table 3

values of thickness are used on the higher voltages because the thickness required does not vary directly with the voltage.

In low tension work and in some large transmission systems it is important to have as large a safe current carrying capacity as possible.

The carrying capacity of lead sheathed cables in conduit is dependent upon the (a) size and number of the cables in the conduit, (b) the radiating capacity of the conduit and cable, and (c) the ability of the insulation to withstand high temperatures.

The case may be stated in another way, viz.: the carrying capacity of cables is fixed by the maximum temperature at which it is safe to operate the insulating medium. The size and number of cables carrying a given load fixes the amount of energy released in the conduit line in the form of heat. The resulting temperature is fixed by the radiating capacity of the cable insulation and

APPROXIMATE OUTSIDE DIAMETERS OF ELECTRIC LIGHT AND POWER CABLES.
THREE CONDUCTOR — (⅛ LEAD THROUGHOUT)

SIZE.	Insulation Thickness on Each Conductor, and Over Bunch Respectively Equal to—										SIZE.
	$\frac{5}{64}+\frac{1}{64}$	$\frac{3}{32}+\frac{1}{32}$	$\frac{3}{32}+\frac{3}{32}$	$\frac{4}{32}+\frac{4}{32}$	$\frac{5}{32}+\frac{5}{32}$	$\frac{6}{32}+\frac{6}{32}$	$\frac{7}{32}+\frac{7}{32}$	$\frac{8}{32}+\frac{8}{32}$	$\frac{9}{32}+\frac{9}{32}$	$\frac{10}{32}+\frac{10}{32}$	
	DIAM.	DIAM.	DIAM.	DIAM.	DIAM.	DIAM.	DIAM.	DIAM.	DIAM.	DIAM.	
10	772	939	1095	1292	1490	1686	1885	2081	2280	2476	10
8	865	1032	1157	1353	1552	1748	1947	2143	2342	2538	8
6	949	1117	1242	1437	1637	1832	2032	2227	2427	2622	6
5	1028	1164	1289	1485	1684	1880	2079	2275	2474	2670	5
4	1084	1218	1343	1539	1738	1934	2133	2329	2528	2724	4
3	1145	1281	1406	1602	1801	1997	2196	2392	2591	......	3
2	1216	1352	1477	1673	1872	2068	2267	2463	2662	......	2
1	1300	1436	1561	1757	1956	2152	2351	2547	......	......	1
0	1389	1525	1650	1846	2045	2241	2440	2636	......	......	0
00	1488	1624	1749	1945	2144	2340	2539	2735	......	......	00
000	1600	1736	1861	2057	2256	2452	2651	......	......	......	000
0000	1723	1860	1985	2180	2380	2575	......	......	......	......	0000
250,000	1825	1961	2086	2282	2481	2677	......	......	......	......	250,000
300,000	1944	2080	2205	2401	2600	......	......	......	......	......	300,000
350,000	2052	2188	2313	2509	2708	......	......	......	......	......	350,000
400,000	2153	2289	2414	2610	......	......	......	......	......	......	400,000
450,000	2251	2387	2512	2708	......	......	......	......	......	......	450,000
500,000	2343	2479	2604	......	......	......	......	......	......	......	500,000

Table 4

the duct system. It is apparent that the ducts which are inside and have no direct contact with the concrete casing of the duct line will run warmer than those around the edge. Likewise it is natural that the inner conductors of concentric cables should run hotter than those next to the sheath. The exact effect of such relations has been studied by Fisher in connection with the Niagara Falls Power Company's system, by Ferguson in the Chicago central station system and others. In general the result of such tests indicates that with a nine-duct line, the rating of the cable should be reduced to about 85 per cent. of its capacity when a four duct line while in a 16-duct line it may be reduced to 60 per cent.

The carrying capacity of a multiple-conductor cable is reduced because of the greater amount of energy which must be dissipated per foot of cable. The Standard Underground Cable Company is authority for the statement that duplex cable has 87 per cent. of the carrying capacity of single-conductor, concentric cable 78 per cent. and three-conductor 75 per cent. The heat conducting power of rubber is somewhat better than that of oiled paper, and a given thickness of rubber insulation may therefore be relied upon to convey more heat away from the conductor than the same amount of paper. However, the maximum temperature at which rubber should be operated is about 65° C. and the ampere load on a rubber-covered cable should not be such as to run the temperature beyond this point. The temperature of paper cables may at times be pushed above this figure, but if operated continuously about 85° C., the insulating value of the paper will be injured.

The carrying capacity of certain of the more common sizes of single-conductor load cables and the watts per foot at 65° C. are given in the following table:

Size..................................	6	4	2	1	0	0000	300	400	500	750	1000	1500	2000
Current................................	64	91	125	146	168	260	323	390	450	583	695	895	1085
Watts. Per Foot........................	1.85	2.31	2.77	3.0	3.23	3.92	4.22	4.61	4.91	5.46	5.86	6.49	7.09

Tests reported by Ferguson in his paper before the Electrical Congress at St. Louis in 1904 furnish very useful data as to the temperatures attained in paper insulated cables laid in underground conduits. Fig. 5 shows the rise in temperature experienced by a 1,000,000 cm. single-conductor cable, in tile duct, and in air, when carrying loads from 800 to 1900 amperes. It will be noted that at a load of 1000 amperes, the rise of temperature of the cable in the air is 41° C. while in the conduit it is about 10° C. higher.

The results represented by the curve in Fig. 6 show the rate of rise of temperature in a two-conductor concentric cable of 1,000,000 cm. in each conductor when it is carrying 1000 amperes. It is apparent from the curves that the temperature of the outer conductor is practically the same as that of the single-conductor cable of the same section in air, but that the inner conductor runs hotter. The rate of rise is such that the ultimate elevation of 40 per cent. in the outer conductor is reached in about 2½ hours, 70 per cent. of this rise having occurred in the first hour. Overloads of short duration may therefore be carried safely. Data for a three-conductor cable of 4/0 in conduit are given in Fig. 7 for various ampere loads. This cable was loaded with an equal current in each conductor and it is apparent that with equivalent current densities, this cable runs cooler than the 1,000,000-cm. cable. This is due to the fact that the radiating

Company.	Line Voltage.	Kinds of Insulation.	Thickness of Insulation in Thousandths of an Inch.			
			Between Conductors.	Between Conductors. and Ground.	Per 1000 V.	
					Between Conductors.	Between Conductors and Ground.
New York Edison..................	6,600	Paper	312	312	47	47
N. Y. Metropolitan...............	6,600	"	436	343	67	52
Commonwealth Edison..............	9,000	"	406	383	44	38
N. Y. Sub. Co....................	11,000	"	436	468	40	43
N. Y. Manhattan..................	11,000	"	436	436	40	40
Buffalo Niagara L................	11,000	"	406	406	37	37
Milwaukee........................	15,000	"	500	437	33	29
St. Paul.........................	25,000	"	562	484	22	19
Montreal.........................	25,000	"	562	406	22	16

Table 4A

surface of the three-conductor cable is over 60 per cent. greater than that of the single-conductor 1,000,000-cm. cable.

The most convenient terms in which to express the load on cables

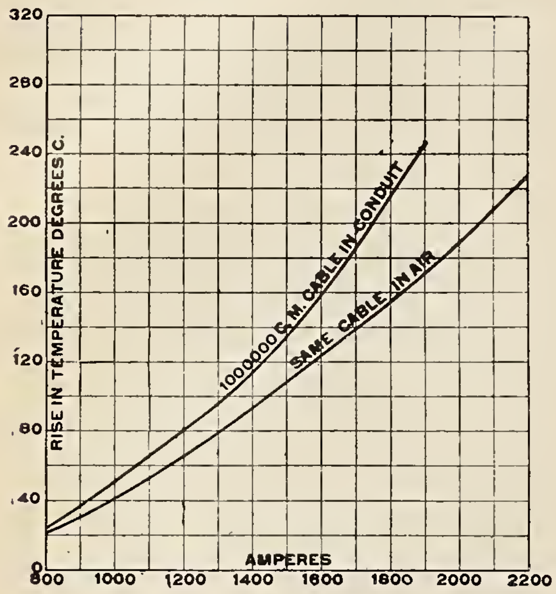


Fig. 5

is in watts per duct foot, as the heating of cable and air is directly proportional to this quantity.

The resistance of a 1,000,000-cm. cable being 0.0000124 ohm per ft. at 50° C., the energy loss C^2R in a single conductor cable at 1000 amperes is $1000 \times 1000 \times 0.0000124 = 12.4$ watts. Likewise in a 1,000,000 concentric cable the loss is 24.8 watts per ft. In a three-conductor 4/0 cable, with 200 amperes current in each conductor, the resistance per ft. being 0.00006, the loss per foot. of cable is $3 \times 200 \times 200 \times 0.00006 = 7.2$ watts. With smaller conductor the energy loss is less for a given current density, and the surface of radiation not decreasing proportionately, the current density may be run above 1 ampere per 1000 cm.

In placing cable in the duct system, a uniform method of selecting

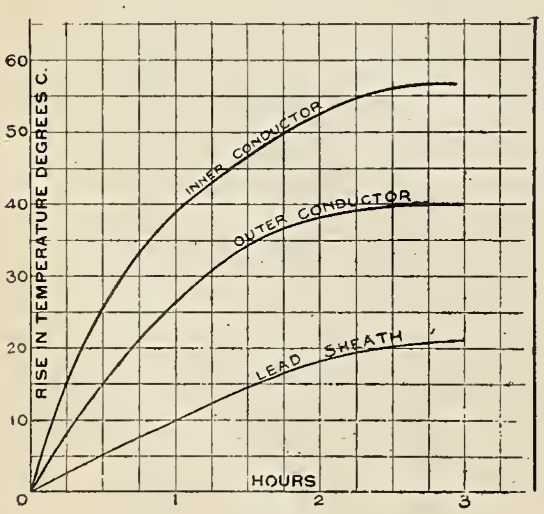


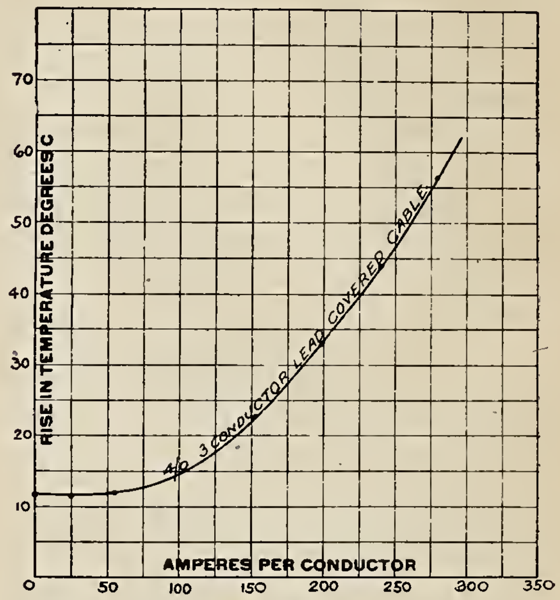
Fig. 6

ducts should be followed as far as possible. The cable of a given line should occupy the same relative position throughout its course as far as this is possible. Cables used in local distribution should be given a uniform place in the duct system, preferably in the top row, so that handholes can be built between manholes for service laterals without sinking them below the top row of ducts. The lower ducts are thus left vacant for through lines which may be trained through the manhole below junction boxes, fuse boxes, etc., which it is desirable to mount on the walls of the manhole.

Ducts should be selected for through lines so that they may be trained where the line changes direction with the least interference with other cables. If cables become interlaced it is very difficult to get at them to make repairs or alterations, and the danger of an arc spreading to adjacent cables cannot be guarded against properly. The routing of through lines should be such as to utilize duct lines to the best advantage. The extra ducts on streets remote from the station should be utilized to reduce the extent of the heavy duct lines radiating from the station, as shown by the routing of lines in Figs. 8 and 9. It is apparent that the congestion of cables near the station is less in the arrangement in Fig. 9 than in Fig. 8. It should be borne in mind that when a short section of a duct line is used the remaining portion may be rendered useless for through lines. It is therefore desirable to follow a route in a given direction as far as it is desired to go in that direction, except near the station where lines must be taken out in large numbers far enough to permit of separation into smaller runs.

Vacant ducts which are blocked off in part of a route by use of the corresponding duct in the remainder of the route are likely to remain idle investment, and where it is necessary to use a short length of a duct route it will often be better economy to build the extra ducts over the short section than to use a part of the ducts designed for the main route.

The cable having been selected for the requirements of the service it is to render, it is very important that it be properly installed and jointed, as the best of cable may be rendered useless by ignorance or carelessness of the principles governing a safe installation. The best practice for those who do not have enough cable jointing to maintain a force of men throughout the season, is to make their contracts for cable so as to include the installation and jointing work. The responsibility for any failure is thus centered at one point and is not likely to be evaded. However, with a growing system additions to the underground lines are constantly being made and it is desirable to have a force of men who can do such work and joint it up



Curve showing relation between temperature and current in 4/0 3-conductor lead covered cable

6-32 in paper wall over each conductor

4-32 in. paper wall over the three conductors

4-32 in lead outside wall

Test made with cable in conduit in cold weather Other cables in conduit are not heavily loaded

Fig. 7

properly even though they have to be used on other kinds of work between times. The methods used in the installation of cables should therefore be familiar to central station engineers who have underground lines in their systems.

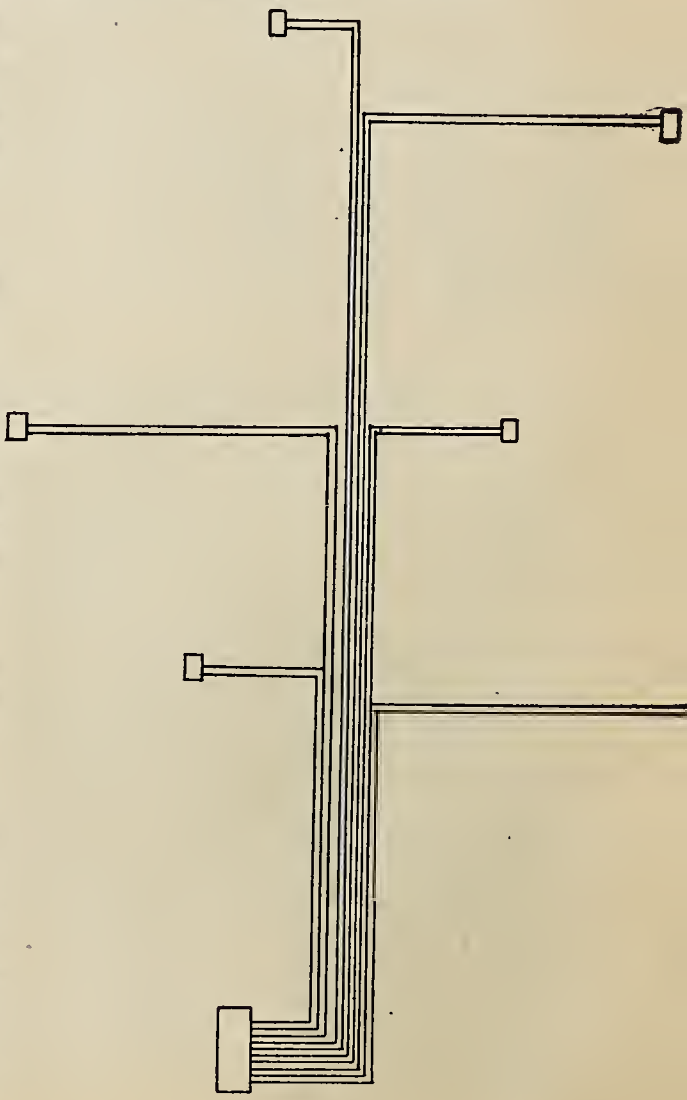


Fig. 8

The first step in the introduction of a cable into a duct is the rodding of the duct. This is done for the purpose of introducing the line by which the cable is to be drawn in. The rods consist of lengths of wood about one inch in diameter by three feet long, provided with detachable hooks so shaped that the lengths may be pushed into a duct until they project into the next manhole. They are then drawn through with the pulling line attached and disjointed as they come through. In some cases this work has been done by having a light line attached to a ferret, and sending the ferret through the duct after a rat.

When the cable-pulling line is ready for use, it is run over pulley wheels out of the manhole and to the source of power. The reel of cable is set up on an iron bar so that it will revolve and pay out cable as it is drawn in. Enough men are placed at the reel and in the manhole to guide the cable into the duct and prevent its sheath being injured

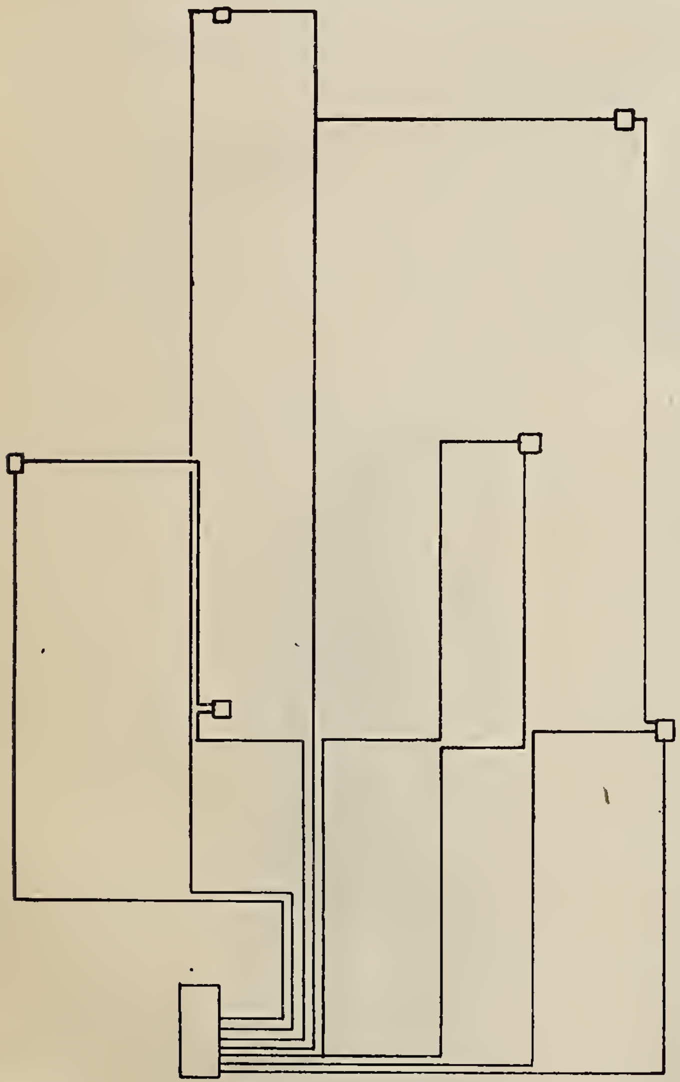


Fig. 9

as it passes through the manhole opening.

Power is supplied for pulling in various ways. With short runs and small cable, a few men can draw the cable in. With runs of 300 to 500 ft., the most general power is a capstan manned by six or eight labor-

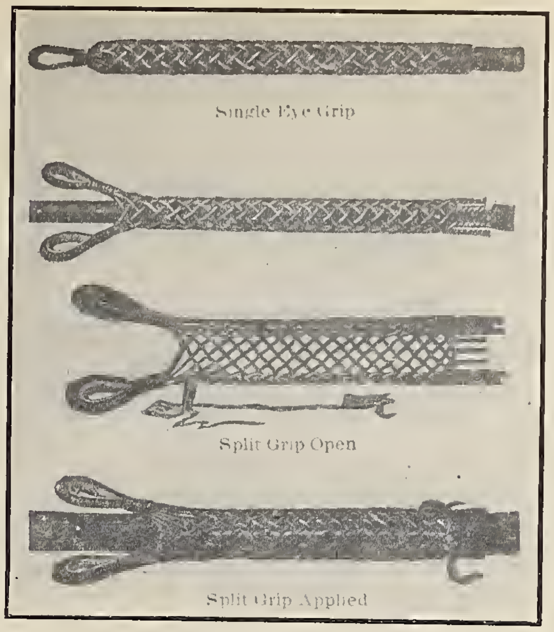


Fig. 10

ers. In some cases when heavy three-conductor cables are being pulled in long runs, an automobile truck has been used to advantage, the speed of the truck being reduced by block and tackle and by running the truck at slow speed. This permits of work being done more rapidly than with a capstan. The cables are secured to the pulling line by baring the copper and making a secure connection mechanically by wrapping. Large cables are sometimes secured by a special form of cable grip shown in Fig. 10. This is quickly attached and removed and saves considerable time. The wear is considerable, however, and the grip must be renewed frequently.

Where several cables are to be drawn into one duct they should be installed simultaneously by securing them to one line, as, if it is attempted to pull them separately, the duct cannot be utilized as freely as it should. Five single-conductor cables of any size up to No. 4 can be drawn into a square 3½-inch duct without danger of injury.

Small cable is usually put up on reels and cut to fit as it is drawn in, but a length of about 400 ft. of three-conductor or high-voltage cable, or 1,000,000-cm. feeder cable, fills a reel, and it is therefore usual to order such cable in specified lengths. The distance from center to center of manhole plus the amount needed for training around the walls of the manhole and splicing, is the length to be ordered. The reels are marked for delivery at certain street intersections and with the length of cable which they contain. It is important that such lengths be determined within a few feet as all short ends cut off by the jointer are of value only as junk, and may represent a considerable sum of money on a large job, where the cable costs from $1.00 to $2.00 per ft. The training of cable through manholes must be carefully done to avoid sharp bends, tangled relations with other cables and possibility of injury due to exposure to workmen's shoes while entering or leaving the manhole. It is customary to support cables in some localities on iron racks hung on the brickwork of the walls. In other cases brickwork shelves are built around the walls on which the cable is laid. In some large systems the important cables are laid in split tile ducts carried on shelves around the sides of the manhole. The tile is made in short lengths with curved pieces suitable for covering the bends and being in two parts is easily applied after the cable is drawn in and jointed. The tile serves to protect adjacent cable from injury in case a transmission cable fails and also from possible injury from mechanical interference during the progress of work on other cables in the manhole.

Where high voltage cable is carried through manholes on iron racks without protection, the failure of the cable at one point is apt to charge the lead sheath, and cause it to be damaged in adjacent manholes where the current attempts to pass from the lead to ground through the iron racks. It is usual to protect high tension cables in manholes to prevent the communication of trouble to other cables than the one which fails. This is done by wrapping them with asbestos tape, or some similar fireproofing material, in some cases, and in others by the use of split tile or brick shelving as described above. The tile is the most expensive but forms the surest protection where large station capacity is back of the short circuit. Where lines are carrying loads of 1000 kw. or more, of important light and power service, the extra cost of the tile protection is amply justified.

With paper cables particularly and with other cables as a rule, the radius of bends must not be made too small. The shape of the manhole walls and the manner of bringing the ducts into the walls should be designed with this in view. Generally, the radius of a bend should not exceed eight or ten times the diameter of the cable. This is one of the chief limitations in the use of heavy concentric and multiple-conductor cables whose diameter is such that they could be trained through manholes with difficulty if larger sizes were attempted. In case of changes which necessitate the withdrawal of cable, the larger sizes may be ruined in passing over the idler

wheels as the cable emerges from the manhole due to the necessarily small radius at which it is bent. It is therefore necessary to devise special means of pulling cable out without subjecting it to strain in passing over the idlers as is usually done with smaller cables in some cases.

As soon as the lengths are drawn in the ends should be sealed to exclude moisture unless they are to be jointed at once. The work of jointing requires the services of an expert, especially with high tension paper cables. In jointing single-conductor cables, the lead sheath is removed four to six inches back from the end of each piece of cable and enough of the copper bared to permit a good soldered connection being made as in any other cable of similar section. After soldering, the bare parts are wrapped with tape of the same material as the insulation until the equivalent of the cable insulation has been applied. A lead sleeve which has previously been slipped back over one of the cables

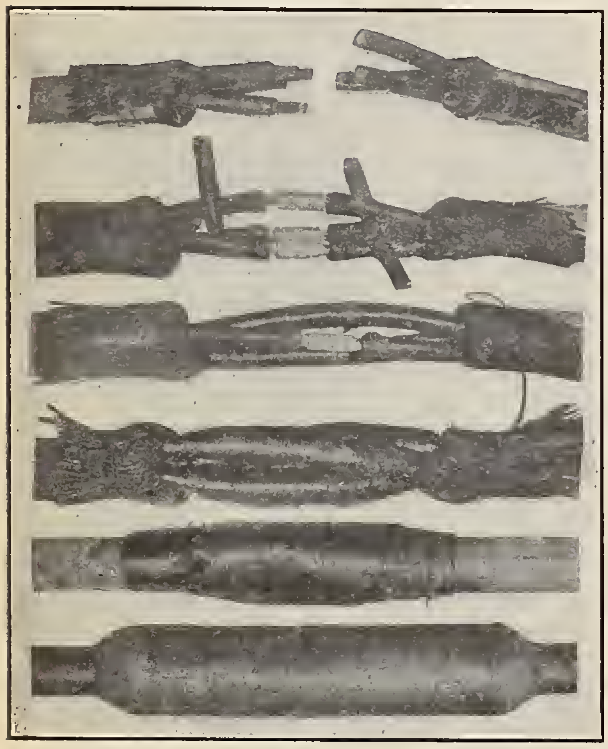


Fig. 11

is now wiped on to the two cables so as to enclose the joint. The air spaces around the joint are then filled by pouring hot insulating compound into a small hole in one end of the sleeve until it does not settle down further.

A similar hole should be left open in the other end of the sleeve to allow air to escape easily while pouring the compound. The openings in the lead sleeve are then closed by soldering, thus sealing the joint from moisture. The joint should be allowed to cool before it is moved so that the relative positions of the conductor and insulation will not be disturbed. The various operations of joining a three-conductor cable are illustrated in Fig. 11.

In jointing three-conductor cables, the load must be cut away further

Fig. 12

back to facilitate the separation of the conductors while the tape is being applied. If any sign of moisture appears in the ends of the cable, the end of the cable should be cut back until it is eliminated. If this cannot be done without removing too much, it may be necessary to drive it off by heating the cable with a blow-torch several feet back from the end.

The presence of slight amounts of moisture should be guarded against by pouring hot compound over the bared ends. The compound should be hot enough to boil water, but not so hot as to char a piece of paper. In making joints for voltages of 6000 and higher some special precautions are necessary. It is very important that as little air remain in the taping as possible. If paper tape is used each layer should have compound poured over it before the next is applied. Some cable manufacturers prefer to use a cotton tape for this purpose on account of its absorbent qualities. Some of the most successful cable systems have been jointed with specially prepared paper tubes. These are slipped back over the conductors before they are joined and are later secured in place over the taped joint, thus making a rigid mechanical separation between polarities. A large tube is slipped over all three conductors as further insulation to ground. The lead sleeve must be large enough to slip over the taped joints, and in three-conductor cable the space taken by the joints is such that the diameter of the sleeve must be from 1 inch to 1¼ inch more than that of the cable. With single-conductor cable, ½ in. to ¾ in. more is usually enough. Where a tap is to be taken off, the sleeve may be arranged at right angles in the form of a T, or at an acute angle as in Fig. 12. The T joint is usually difficult to dispose of on the manhole wall without straining the sleeve, while the other form may be trained along with the cable to which it is tapped.

Where single-conductor cables are joined to multiple-conductor, the joint is made in a similar manner, the single-conductor cables being flared out slightly, to insure proper separation and to permit the proper wiping of the sleeve.

Such joints are more difficult to make than straightaway splices and require considerable skill. The jointer requires the services of a helper in preparing the lead sleeves, heating solder and compound and guarding the entrance to the manhole. A three-conductor high-tension joint in a paper cable usually requires about four to five hours to complete, two joints a day being a fair rate of progress in such work. Single conductor and low-tension cables do not require as long a time.

In most primary distributing systems in which part of the lines are underground, there are connections made between underground and overhead lines. It is usual to run feeders and important mains underground for some distance from the station in large cites, and then connect wth overhead lines in the more scattered areas.

Fig. 13

Where alley distribution is general the main lines are placed underground on streets at intervals of about one-half mile, and the local distributing taps taken off to overhead lines in alleys. In other locations lines must be carried under-

ground across a boulevard, railroad, or stream. This class of distribution was for many years very troublesome because of the difficulty of properly caring for the cable ends which are brought up the pole to the overhead lines. Plain joints made by stripping the lead back a few inches and covering with tape and compound were succeeded by wiped lead sleeves filled with compound and left open at the end where the line wire came out. In some cases the joints were protected by enclosing them in wooden boxings. All of these various forms were susceptible to the action of sun and rain, and were sooner or later located by lightning flashes or otherwise as the weak spots in the line. In recent years most of the large systems have been equipped with a form of porcelain pothead devised by the authors to meet such conditions as they arose in great number in Chicago. The device is illustrated as applied to a single-conductor cable in Fig. 13 and the manner of installing them is shown in Fig 14.

The insulation is thoroughly sealed from moisture by the filling of hot compound. The cap being similar to an insulator sheds all water when properly taped and may safely be handled by a lineman when the circuit is alive at any pressure up to 5000 volts. The metal connectors provide means for opening or closing the circuit with ease for repair or alteration work when desired. Other forms have been devised for cables carrying currents of 100 amperes and upward and for multiple conductor cables, which

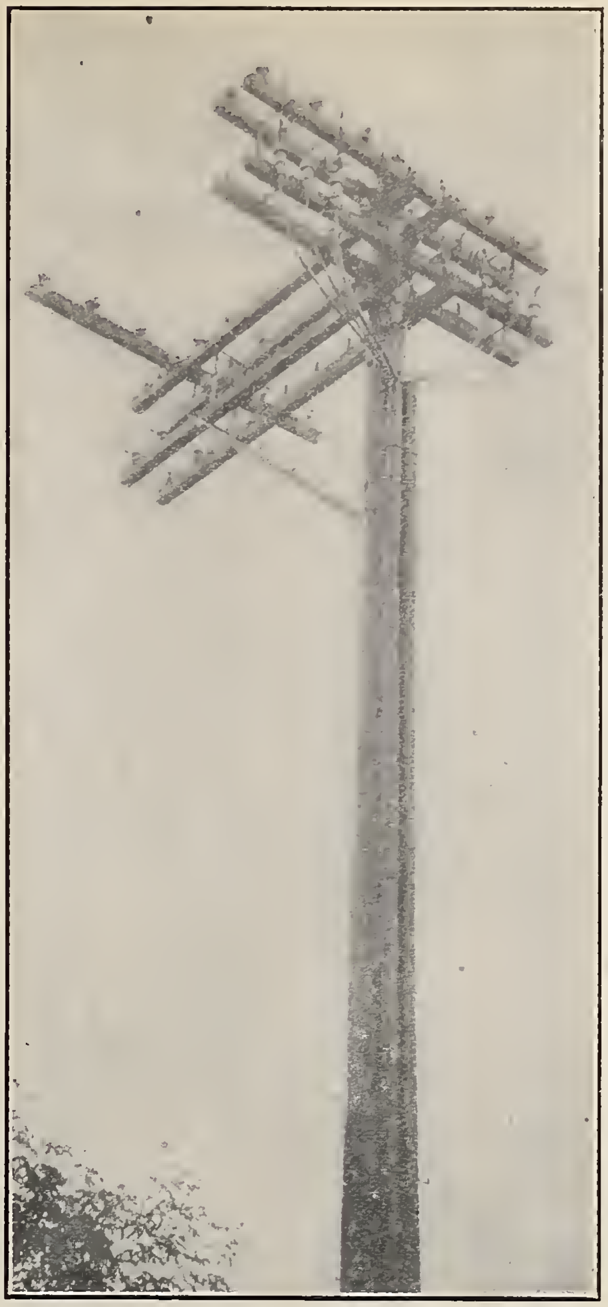


Fig. 14

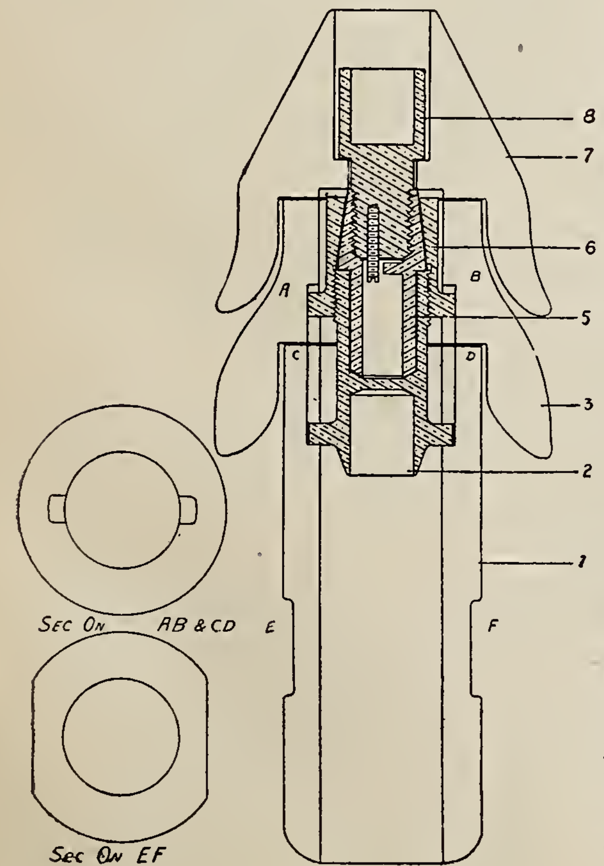


Fig. 15

are shown in Fig. 15 and Fig. 16 respectively.

The arrangement of transformers, fuse boxes, junction boxes and similar accessories in manholes should be worked out with care and foresight. Such apparatus should not be so placed in manholes as to obstruct the introduction of other cables at a later date or to make a neat and orderly arrangement of cables impossible. It is, first of all, important that manholes in which the larger pieces of apparatus, transformers or low-tension junction boxes are to be placed should be of ample size to accommodate them properly.

Low-tension junction boxes for use in manholes are of two types, one of which is mounted on the wall in a vertical position, while the other is placed horzontally in the roof of the manhole with a separate cover so that it is accessible for replacing fuses or cleaning contacts above ground. The former type is perhaps the best as regards the training of cables as they may be kept in order on the walls of the manhole. The ability to do maintenance work on the surface is of some advantage in less congested districts where the traffic is light and the drainage of manholes not perfect, but in a busy street it is preferable to be able to do this work in the manhole where it is not interfered with by passing wagons or crowds of curious observers.

In alternating current systems, wall space must be reserved for junction and fuse boxes and floor space is usually required where transformers are installed in manholes.

In the design of the manhole and duct system, ample provision should be made for their proper ventilation. This not only applies to facilitating the exit of the heated air from the ducts themselves, but also to preventing, as far as possible, the entrance of gases that may be liberated in the ground outside. By a tight connection between the duct and the hole, and suitable arrangement for ventilation and draining the latter, the risk of the disastrous explosions that have from time to time occurred may be almost done away with. In some of the larger cities where underground wires are run in "subways," or aggregations of ducts, which are constructed by the municipality and rented to the public utility companies, the provisions made to guard against accidents of this sort have been so successful that an explosion, or, indeed, any disturbance due to poor ventilation has come to be a very rare occurrence.

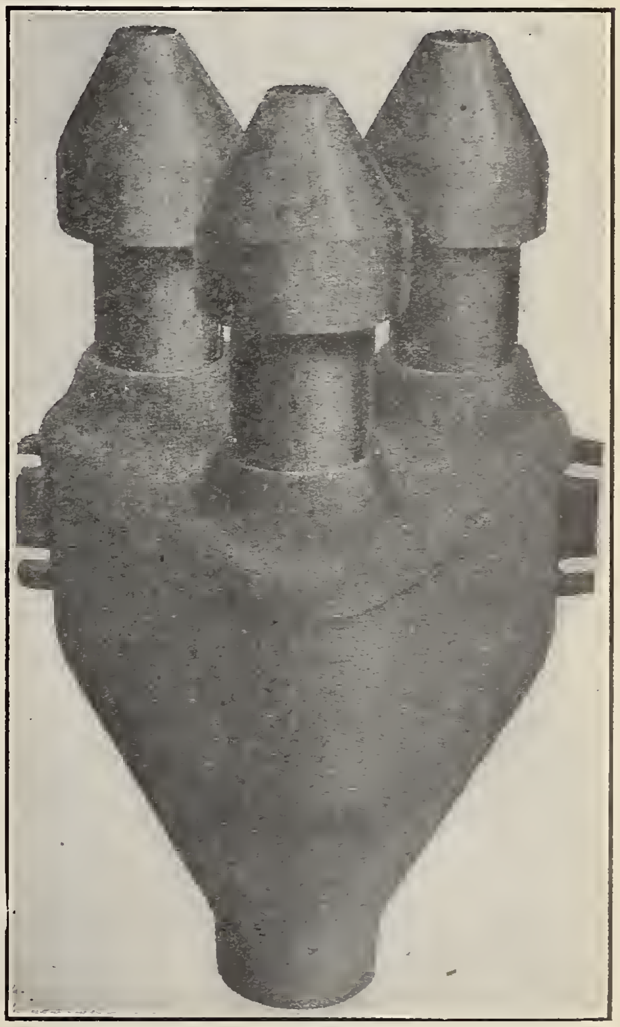


Fig. 16

Power Factor Measured by Wattmeter Readings

THE usual method of metering polyphase power is by means of a wattmeter having two single wattmeter elements mounted on one shaft and registering on one dial, that is, by the polyphase wattmeter. This type of meter as developed by one of the large manufacturing companies gives results that amply repay for its installation. Owing to the rush of increasing business, central stations are not always prepared for new customers and must utilize apparatus in stock for purposes to which it is not adapted. These conditions have led to a very general adoption of single-phase wattmeters to the measurement of polyphase power.

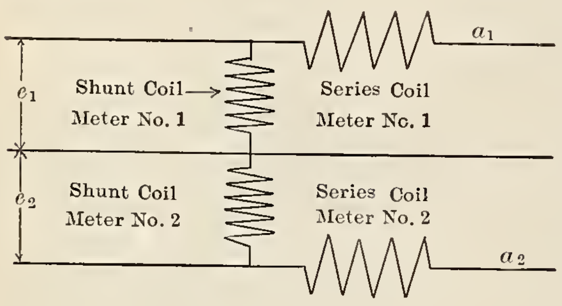


Fig. 1

Two single-phase wattmeters are connected in a three-phase circuit, each with its series coil in series with one wire and its shunt coil between that wire and the wire not connected to the series coil of the other meter. (See Fig. 1.) When the load is balanced the sum of the readings of the two meters gives the amount of electric energy delivered.

The two meters record the same amount of energy when the power factor of the circuit is unity. With power factors less than unity, one meter runs faster than the other, and this difference in readings becomes greater and greater down to a power factor of 50 per cent., when one meter stops. At power factors below 50 per cent. one meter reverses, thus deducting from the kilowatt-hours previously recorded. The ratio of the readings of the two meters corresponds to a definite power factor. Thomas M. Gibbes submits a chart, Fig. 5, which gives this relation in the form of a curve from which the average a power factor of an installation can be determined by means of the readings of the wattmeters which measure the electric energy delivered to that installation.

One of the wattmeters records an increase in total kilowatt-hours registered over that at the previous reading. The other wattmeter may or may not record an increase in kilowatt-hours, depending on the power factor of the load. A reverse reading is of rare occurrence, though provision has been made for such cases by extending the curve to include all power factors. The wattmeters have been designated as Nos. 1 and 2 for convenience in reference. No. 1 is that wattmeter which gives the highest reading.

The method of finding the power factor of the load is to find the point on the curve where the straight line, drawn to represent the ratio of the two readings, intersects the curve. For instance, wattmeter No. 1 reads 700 kw-hr. and wattmeter No. 2 reads 350 kw-hr. The ratio of these readings is represented by the sixth oblique line counting from the top line downward. This oblique line intersects the curve at power factor .865, and the power factor is 86.5 per cent.

If wattmeter No. 2 reads a loss of 350 kw-hr., then the ratio of the readings is indicated by the sixth line from the lowest oblique line, and the power factor is .19 or 19 per cent.

The proof on which the above statements are based runs somewhat as follows:

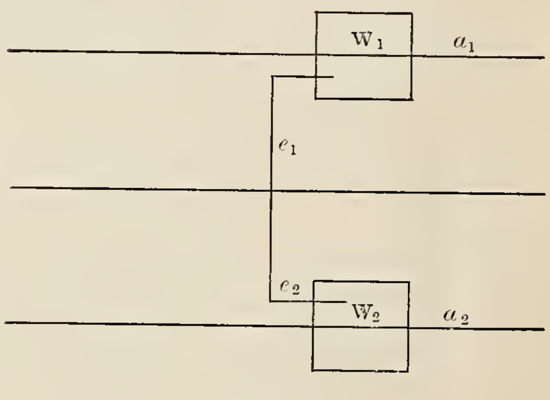


Fig. 2

In a three-phase circuit the power can be measured by two wattmeters connected as shown, and is equal to the algebraic sum of the readings.

Let w = watts read

e = voltages

a = currents

$w_1 = e_1\, a_1 \cos\theta_1$

$w_2 = e_2\, a_2 \cos\theta_2$

Since $e_1 = e_2$ $\quad \dfrac{w_1}{w_2} = \dfrac{\cos\theta_1}{\cos\theta_2}$

and $a_1 = a_2$

Now $\theta_1 = \phi - \alpha$ and $\theta_2 = \phi + \alpha$

$$\therefore \frac{w_1}{w_2} = \frac{\cos(\phi - \alpha)}{\cos(\phi + \alpha)}$$

and since $\alpha = 30^\circ$ $\tan\alpha = \dfrac{1}{\sqrt{3}}$

Substituting we get

$$\tan\phi = \frac{w_1 - w_2}{.577\,(w_1 + w_2)}$$

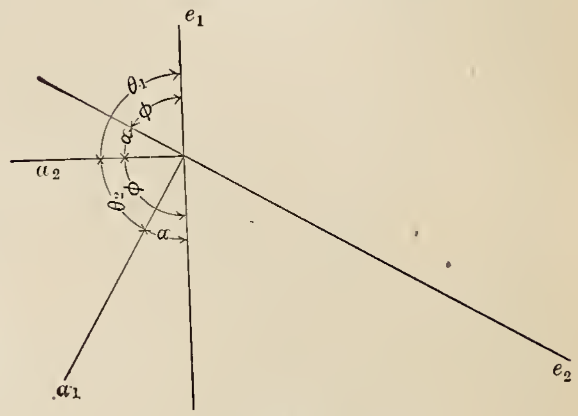


Fig. 3

On axis O X lay off w_1

On axis O Y lay off w_2

From A as center draw semi-circle B < D, then E B = $w_1 - w_2$, and on E D = $w_1 + w_2$ lay off O F = $w_1 - w_2$. By construction lay off O H = $.577\,(w_1 + w_2)$, then tangent of angle I O L = $\dfrac{(w_1 - w_2)}{.577\,(w_1 + w_2)}$ = $\tan\phi$. Draw circle I J K with radius equal to 1. Then O L = $\cos\phi$. Lay off M N perpendicular to O X and equal to $\cos\phi$. Draw O T through F I and from M draw M Q

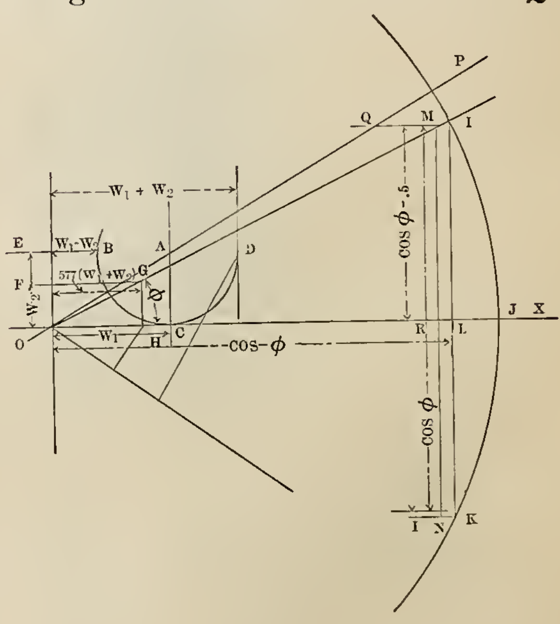


Fig. 4

parallel to O I, then Q is point on same and other points can be found similarly.

$$\text{Tan } \phi = \frac{w_1 - w_2}{.577\,(w_1 + w_2)} = \frac{\sqrt{3}\,(x - y)}{(x + y)}$$

$$\text{but tan } \phi = \frac{IL}{OL} = \frac{\sqrt{1 - \cos\phi^2}}{\cos\phi}$$

$$\frac{\sqrt{3}\,(x - y)}{(x + y)} = \frac{\sqrt{1 - \cos\phi^2}}{\cos\phi}$$

We then have

$$\cos\phi^2 \left[\frac{\sqrt{3}\,(x - y)}{(x + y)}\right]^2 = 1 - \cos\phi^2$$

and

$$\cos\phi^2 \left[3\,(x - y)^2\right] = (x + y)^2 - \cos\phi^2\,(x + y)^2$$

hence

$$\cos\phi^2 \left[3\,(x - y)^2 + (x + y)^2\right] = (x + y)^2$$

$$\cos\phi = \sqrt{\frac{(x + y)^2}{3\,(x - y)^2 + (x + y)^2}} = \sqrt{\frac{(w_1 + w_2)^2}{3\,(w_1 - w_2)^2 + (w_1 + w_2)^2}}$$

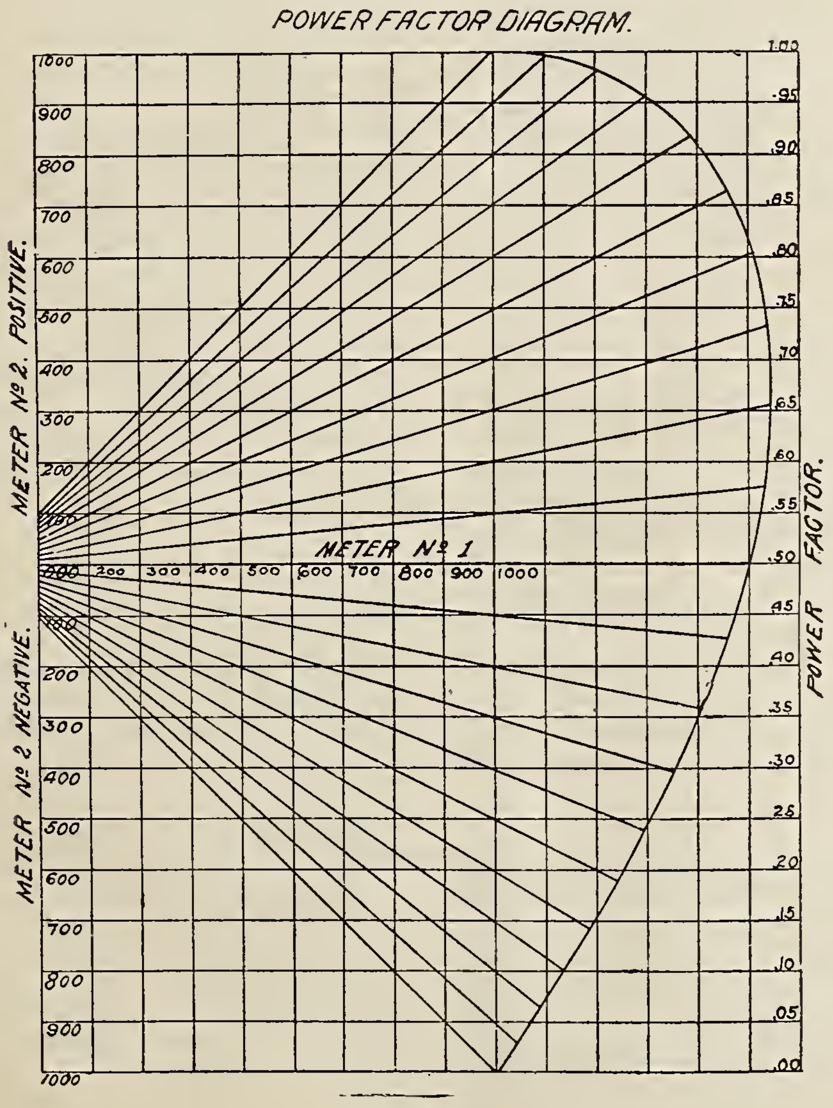


Fig. 5

Cos ϕ may therefore be taken proportional to the power-factor, which is the quantity under discussion.

Readings of indicating wattmeters may be utilized for finding the power factor at the time of taking the reading. With two indicating wattmeters connected as per Fig. 1, a reading of 700 kw. on wattmeter No. 1 and 350 kw. on wattmeter No. 2 indicates a power factor of 86.5 per cent. at the time of taking the reading. Readings must be taken at one time. It is important that the load be balanced or the results obtained will not be anywhere near accurate.

The chart is plotted accurately from calculation, as it is intended to be a labor-saving device. However, some will prefer to plot a curve with the ratio of wattmeter readings and the power factor as coordinates. This can readily be done. Readings of 700 and 350 give a ratio of one-half and power factor 86.5 per cent., similarly all the points may be plotted to include all power factors. A curve obtained in this way is simpler than the chart, but the ratio of the wattmeter readings must be calculated every time a power factor is to be obtained.

Some central stations are now equipped with graphic recording power-factor meters, which indicate the power factor at all times and record on a strip of profile paper the power factor accurately in per cent. Results can thus be compared with results secured at any previous time, and defects or improvements noted.

The power factor of small feeders and that of any installation is measured with a portable power-factor meter of the size and general appearance of a voltmeter. Small series and voltage transformers are made for use with this meter, so that one set suffices for measuring any load at any voltage.

Buying on Chemical Specifications

Where dimensions, weight, finish and the like may be readily expressed in specifications, it is easy and natural to make them conditions upon which purchases shall be accepted. But where strength, chemical composition, durability and similar factors of ultimate efficiency are of importance, specification of these features is all too often omitted.

The reason is obvious, tests must be applied which usually call for equipment, knowledge and experience beyond those possessed by the average buyer. He is then obliged to turn to the expert, but objects because of the initial expense and fails to recognize the ultimate economy.

In every industry some material is being bought on the basis of brand, reputation, or even satisfactory experience in its use without the least idea that equal efficiency might be obtained at a lower price with a suitable material whose composition could be specified in advance by the chemist. But where the purchaser is alive to all such savings they may be made to aggregate a considerable net amount after all expert service is paid for. The following experience is suggestive:

The purchasing agent of a large electric railway company was recently buying of a reputable supply house a metal for journal linings, which gave good satisfaction. He was paying 20 cents a pound and, in view of the nature of the material, felt that the price was high. A sample was submitted to the Arthur D. Little Laboratory in Boston for analysis. Upon receipt of their report the purchasing agent sent out for bids upon a metal of the composition shown on analysis. A reliable concern at once offered such a metal at six cents per pound. As the amount of metal used in a year was large, the saving by having the same metal made to their formula was well worth obtaining.

Growth of Telephone Service

The forecast of the annual report of the New York and the New York and New Jersey Telephone Companies indicates that their earnings are larger than for any previous year. In spite of the so-called depression more than 50,000 new instruments have been connected in the Metropolitan district, the total number on Oct. 1, 1908, being 420,173.

Questions and Answers

Question.—*We have a load consisting of 85 old style 32-c-p. 110-volt carbon filament lamps, put five in series on a 550-volt circuit. I figure they take nearly one ampere per cluster and wish to know what the losses in the circuit would be using No. 10 wire. The voltage is to be regulated to 550.*

Answer.—You do not state the length of wire in the circuit, so it is impossible to figure the losses. If the current in the lamp-clusters is one ampere for each and the voltage is 550, the resistance of the lamps and wire must be about 550 ohms and the loss would be 550 watts for each group, or $\frac{550 \times 17}{1000} = 9.35$ kw. for the whole load.

Question.—*Lately we have heard a great deal about "Load Factor." Please explain what is meant by this phrase and why it is of such importance.*

Answer.—In the early days of the central station industry, charges for the service were made on a flat-rate basis. Later, when the waste and increasing demand had driven the flat rate out of existence, charges were based on the wattmeter readings at so much per kilowatt-hour. It was then discovered that the cost of production was not entirely proportional to the kilowatt-hour produced, but that a large element of the cost, known as fixed charges, which included interest, amoritization, depreciation, etc., on machinery necessary to supply the greatest probable demand was constantly going on whether the output metered was great or small. The disproportion which existed between expenses and income soon raised the question as to what proportion of the rated output was being actually obtained from the machinery installed, and how should the service charges be arranged to provide for the fixed charge element of the total cost of the kilowatt-hour sold, as well as for the fuel element. After much discussion in this connection, practice seems to have settled on the definition "load factor" as the ratio of the average load (for any given period, usually a year) in kilowatt-hours, to the rated capacity of the plant in kilowatts multiplied by the number of hours considered. For a year these would be 8760, so that the expression for the load factor would usually be:

Load factor equals yearly output in kilowatt-hours divided by rated capacity in kilowatts multiplied by 8760.

In addition to the load factor as here defined, there are also two other expressions which have arisen in connection with the discussion. They are the "factor of loading" and the "station load factor," or "curve load factor" as it is sometimes called. The first of these is written as follows:

Factor of loading equals average load in kilowatts divided by maximum load in kilowatts.

The maximum is usually taken as maximum peak lasting over one minute. This ratio is purely a function of the load, and cannot be changed or improved by anything done in the power plant itself.

The station load factor is written: station load factor equals yearly output in kilowatt-hours divided by rated capacity multiplied by actual number of hours that the plant is in operation. Now as the income of a station is based on the metered output and the station expenses are based on fuel and minor incidental costs of the output, plus fixed charges which are approximately proportional to the capacity of the plant, you can appreciate the importance of the ratio between these two quantities which is the load factor.

As an example take a 1000-kw. plant, with a high load factor say about 80 per cent. at a price of 10 cents per kilowatt-hour, the annual production and income would be as follows:

Yearly output, 7,008,000 kw-hr.
Yearly income, $70,080.

Whereas, with a low load factor of say about 20 per cent. the annual output cost would be $1,752,000, and the yearly income $17,520. Yet the *maximum* demands in both these cases might be the same and the fixed charges would be the same in the two cases. The difference in the profitableness of the two suppositions is therefore due entirely to the factor of loading, and its effect on the load factor and consequent economy of the station.

Question.—*We have been operating on a 110-volt single-phase, 133-cycle alternating current circuit, and recently changed over to 60-cycle circuit of the same phase and voltage. We find that in order to keep the same voltage at our customers' premises we do not need to have the station voltage as high as heretofore. At the same time we have several arc lamps that burned out as soon as we changed over. Will you kindly explain the results?*

Answer.—The inductive drop in the line and transformers varies directly with the frequency, consequently it would be less at 60 cycles than at 133 cycles. Naturally, this being the case the drop in the line is less and, therefore, a less station voltage would have to be maintained in order to get the same voltage at the terminals of the line. The arc lamps were designed and connected with a certain amount of reactance for 133 cycles. Of course, when the 60-cycle current passes through these lamps there is a less reactive drop, with the consequent result that the current is increased and the lamps burn out. In most of the standard arc lamps on the market there is a coil in the lamp which enables the lamp to be run on different frequencies by simply changing the taps.

Question.—*In order to increase the speed of a direct-current shunt-wound motor the field is weakened. A direct-current wattmeter is, we are told, the same as a motor. How is it that by increasing the field-current of the wattmeter the speed is increased?*

Answer.—It is true that the direct-current wattmeter is a motor. It is a motor, however, with very little, if any, iron in the field. With any motor the torque is proportional to the product of the magnetic flux and the current. If there is no, or very little, iron the torque is proportional to the current. The armature of the meter is connected directly across the line and its speed is proportional to the e.m.f.'s generated, and the current therein is also proportional to the e.m.f. The torque of the motor is, as above stated, proportional to the current in the windings, therefore, the torque is proportional to the speed, and in the same manner the speed is proportional to the current.

A Jovian Correction

At the Sixth Annual Meeting of the Rejuvenated Sons of Jove, held in Buffalo, N. Y., Mr. Alex Henderson, of New York City, offered a resolution that at the close of each annual meeting the assembled Jovians drink a standing toast to the First Jupiter, Chas. W. Hobson, No. 1, of Dallas, Tex., to the following sentiment:

"A single rose-leaf passed before a man while he is alive is productive of more happiness and joy than a mountain of flowers heaped upon his grave."

In the account of the proceedings of that meeting, prepared for and published by the electrical press of the country, the beautiful sentiment, given above, unfortunately, was quoted incorrectly, entirely robbing it of its delicate fragrance.

In justice to Mr. Henderson, and in justice to the sentiment itself, we gladly publish the correct quotation at the request of the writer of the original article.

Westinghouse Electric

—

Cash Balance at Close of Year, 1907, Aggregated $10,902,000 With $2,346,000 Due on Stock Payments.

—

The Westinghouse Electric & Manufacturing Co. starts the year under very favorable conditions. Its total cash balance December 31, 1908, aggregated $10,902,338. Including unpaid balance on stock subscriptions of $2,436,340, the total cash balance on December 31 was $13,248,677.

The following statement gives the cash resources of the company at the present time:

Bank balances January 4	$9,277,337
Deposited in New York December 31, report received in Pittsburgh, January 2	89,880
Special deposit	1,536,120
Total cash balance December 31, 1908	$10,902,337
Unpaid balance on stock subscriptions	2,346,339
Total cash balance December 31, 1908, including unpaid balance on stock subscriptions	$13,248,677

The sinking fund payment due December 31, and all interest on funded debt due January 1, has been deducted from the above balances. The bank notes as of October 23, 1907, payable in cash and not yet presented, amount to $25,000, and the accounts payable as of October 23, 1907, payable in cash and not yet paid, aggregate approximately $12,000.

The Westinghouse Electric & Manufacturing Co. has sent out checks for $562,725, representing interest due to-day on bonds, debentures, etc., set aside $500,000 due to the sinking fund on December 31, 1908, and paid $220,000 in settlement of sundry debts, preliminary to the opening of a new balance sheet.

The company is now in a very strong position, a great deal of the credit for which is due to George Westinghouse, who was largely instrumental in raising $17,785,000 necessary to the discharge of receivers.

Co-operation between the Central Stations and the Electrical Manufacturers

During the past few years the manufacturers of electrical machinery have been realizing that the extension of central-station business means indirectly the extension of their own business. With the end in view of encouraging the general adoption of electrical conveniences in the house, some of the more progressive manufacturers have been conducting an extensive campaign of educational advertising in non-technical magazines. This policy is based on the obvious fact that there are thousands of well-to-do families who can only be reached in this way.

The story of this activity is set forth in a little publication, "What the Western Electric Company Is Doing to Increase the Central-Station Load." Issued to central-station managers, it shows many of the familiar advertisements that have appeared in the more prominent monthly and weekly magazines. It has met a hearty reception from those for whom it is intended, especially from such stations as are also in the jobbing business. It is far easier for the jobber to sell goods that have been liberally advertised, and the results of the campaign of education are much appreciated by these people.

The Electrical Show

Final preparations for Chicago's January Electrical Show are well under way, and the sale of space has been so large that there is every reason to believe that the coming show will be the most comprehensive and interesting of all the four shows the Electrical Trades Exposition Company will have given. Every branch of the electrical field will be represented and the exposition will maintain its reputation as Chicago's "Billion Dollar Show." Notwithstanding the fact that the scheme of decoration employed last year was outlined as a permanent proposition, at a cost of $25,000, changes will be made for the decoration of the coming show, which will cost, approximately, as much as was expended a year ago. The decorations will be fully as elaborate, employing an entirely new scheme of lighting. Special arrangements are being made for electrical attractions which will be of interest to the general public, and the trade exhibits this year will include more working exhibits than have been shown heretofore. Assistant Manager John J. Schayer, who has had charge of this year's show owing to the illness of Homer E. Niesz, feels particularly gratified with the results as they now stand, and predicts that the January show will draw the banner figures in the matter of attendance. The complete list of exhibitors to date is as follows: Crane Company, Commonwealth Edison Co., Wagner Electric Co., Federal Electric Co., Cutler-Hammer Co., Pyro One-Light Sign Co., Shelton Electric Co., Lindstrom, Smith & Co., Western Insulation Co., National Battery Co., Perfection Vacuum Cleaning Co., Chicago Fuse Wire & Mfg. Co., Electric Appliance Co., The Excello Arc Lamp Co., Kellogg Switchboard & Supply Co., The Stoltz Electrophone Co., Stromberg-Carlson Telephone Mfg. Co., Mathias Klein & Sons, Telephony Publishing Co., Manhattan Electrical Supply Co., Ft. Wayne Electric Works, *Electrical World*, Benjamin Electric Co., *Electrical Record*, Central Electric Co., International Correspondence Schools, McRoy Clay Works, Chicago Pneumatic Tool Co., Robbins & Myers, Appleton Electric Co., United Pump & Power Co., Commercial Appliance Co., Electric City Publishing Co., Taussig & Babcock, *Western Electrician*, Westinghouse Electric & Mfg. Co., Autoelectric Sign Co., General Electric Co., American Steel & Wire Co., National Acme Mfg. Co., Hahl Automatic Clock Co., Swedish-American Telephone Co., Swedish Electric Vibrator Co., Popular Electricity Publishing Co., Peerless Light Co., Palm Engineering Co., Pacific Electric Heating Co., Duntley Mfg. Co., National Automatic Advertising Co., Jewell Electrical Instrument Co., Roth Bros. & Co., Crescent Company, H. W. Johns-Manville Co., Red Cross Antiseptic Co., Northern Electrical Mfg. Co., A. W. Kratz, Illinois Electric Renovator Sales Co., Hurley Machine Co., Murphy Electricity Rectifier Co., National Electric Lamp Assn., Electrocraft Publishing Co., Electrical Testing Laboratories, American Electric Fuse Co., The Caloric Company, The Allis-Chalmers, North Shore Electric Co., Simplex Co., Cyclone Storage Battery Co., Electric Storage Battery Co., F. B. Badt & Co., Chicago Telephone Co., Mechanical Appliance Co., Western Electric Co., The Connersville Blower Co., Electric Cleaner Co., Pelongo Electric Heater Co., C. S. Neville & Co., Men's Ear Phone Co., National Carbon Co., and THE ELECTRICAL AGE.

The show will run from Saturday, Jan. 16th, to Saturday, Jan. 30th—thirteen days against twelve heretofore. There will be several convention and souvenir days.

New Westinghouse Nernst Chandeliers

Besides establishing a new minimum in the price of light of the best quality, the new Westinghouse Nernst system is responsible for the development of a line of chandeliers that give a greater volume of light for a small light source than it is possible to get with any other incandescent chandeliers ever made.

These chandeliers now being put on the market are made in highly artistic designs in Renaissance and Art Nouveau. They are made in solid castings or in a combination of castings and spinnings, and finished as standard in statuary bronze and satin brass.

The novel feature about these chan-

deliers is the arrangement of the mechanism of the lamps in the central ornamental ball which conceals it completely and at the same time makes it easily accessible.

This leaves nothing at the ends of the arms except the small screw base burners, and these occupy less space than any other incandescent lamps of equal candle power. The 132-watt burner, for instance, giving light equivalent to that of seven 16-c-p. carbon filament lamps, occupies a space at the end of the arm of only 3x4½ inches. This makes it possible to get a large volume of light without using a multiplicity of sources or infringing the law of proportions by making the sources too large for the other parts of the chandelier.

Review of the Technical Press

Leading Articles of General Technical Interest

[*Electro-Chemical and Metallurgical Industry,* January.]

"The Largest Electric Steel Works," Joseph W. Richards.

An account of the new 200-ton electrical steel refining works that are being erected by "The Paul Girod Electro-Metallurgical Processes Company" at Ugine in the Savoy. This plant will ultimately absorb 22,000 h.p. and is expected to be put in commission in March. The output will be high quality steel for special purposes.

"Experiments on Melting in the Induction Furnace," F. A. J. Fitzgerald.

Record of test run made by the writer at Niagara Falls with an induction furnace of about one ton's capacity. The energy consumption per long ton was 476 kw-hrs.

"Heat Conductance and Resistance of Composite Bodies," Carl Hering.

A theoretical discussion of the heat-characteristics of different composite structures.

"Smelting Iron Ore in the Electric Furnace in Comparison with Blast Furnace Practice," Joh. Harden.

A comparison of the costs and feasibility of electric furnaces. He finds under the conditions given that the blast furnace process costs $6.84 per ton, while the electric furnace costs $9.70. This is based on charcoal at $12.00 per ton and electric power at $20.00 per kw-year. He concludes that under such conditions the electric furnace would be advisable only in small sizes and in special cases.

"Silundum: a New Product of the Electric Furnace," F. Bolling.

A description of a new form of silicon carbide, which is a sort of a half brother to carborundum and promises to be useful in many ways, as it is very hard and heat-resistant.

[*Electric Journal*—December.]

"Notes on Single-Phase Railways," Clarence Renshaw.

Some observations on the construction and operating of various single-phase railroads equipped by the Westinghouse Electric & Manufacturing Co. The mileage of these roads has now passed the 1000-mile mark.

"Shop Side of Engineering Industries," C. B. Auel.

Dwells on the opportunities and advantages of work in the shop end of the factory as compared with those presented in the office end.

"The Application of Low-Pressure Steam Turbines to Power Generation," J. R. Bibbus.

From the author's paper before the November meeting of the Canadian Society of Civil Engineers. A lengthy discussion of the advantages presented by this, the latest important development in steam turbine practice. Illustrated with several views and curves.

"Three-phase—Two-phase Transmission with Standard Transformers," L. A. Starett.

Shows how, in certain cases, the phase-transformation may be made with ordinary transformers.

"Meter and Relay Connections," Harold W. Brown.

Continues the series, and gives diagrams showing the various connections for three-phase three-wire circuits.

[*Electrical Record*—January.]

"Fire-proof Motors and Switches," F. A. Barron.

Tells of the latest provision for rendering certain special kinds of motors proof against fire and hard usage.

"Advertising Possibilities in Connection with Monthly Central Station Bills," A. E. Hodefield.

Gives some of the latest schemes in the central station advertising field.

[*Electrical Review*—January 1]

"The Corona Effect and its Influence on the Design of High-Tension Transmission Lines," Lamar Lyndon.

Abstract of the author's paper read before the November meeting of the Philadelphia Branch of the American Institute of Electrical Engineers.

A lucid presentation of the effect of this phenomenon on the economy of very high voltage transmission lines, both from a mathematical and experimental standpoint.

Mr. Lyndon first gives a clear description of the corona and its discharges, then discusses in a simple form the mathematical treatment of the problem as presented as indicated by the investigations of Steinmetz, Ryan and Mershon, and follows these with several curves showing the relation between the losses and sizes of the conductors and between the losses and conditions of the atmosphere.

The case of a 100,000-kw. 250,000-volt 300-mile transmission line is then taken up and worked out. With jute-cored cables, 1.5 inch in diameter and separated by 90 inches, the total cost is estimated at $14 per kilowatt, not counting the total cost of right of way, with losses and regulation comparable with present practice.

The conclusions reached are substantially the same as previously found by Mershon. The important factors are the curvature of the conducting surfaces, the separation distances between conductors and the condition of the atmosphere.

"Modern Fireboats," O. H. Caldwell.

A description of two electrically propelled fire-boats owned by the City of Chicago. They are propelled by a 660-h.p. Curtis turbine, on whose shaft is connected a 5500-gallon centrifugal pump and a 200-kw. 275-volt direct-current generator, two 250-h.p. 200 rev. per min. variable speed reversing type motors direct-coupled to the propeller shafts. Perfect control is obtained directly from the pilot-house, enabling the boat to be better handled than is possible with steam-driven propellers.

"Belt Leakage in Induction Motors," R. F. Hellmund.

A diagrammatic treatment of certain leakage losses in induction motors and a discussion of the effect on them of various types of windings.

[*Electrical World,* January 2]

"Quarry Street Station of the Commonwealth Edison Company, Chicago," Wm. Keily.

A description of the above plant which is designed for an ultimate capacity of 84,000 kw. The station is of special interest in that it is equipped with 14,000-kw. turbo-generators, which are the largest so far attempted, and that practically smokeless combustion is secured.

"Bituminous Gas-Producer Electrical Plant," Elbert A. Harvey.

A full description of a 2000-h.p. producer gas plant supplying power for the operation of an electrical plant which drives the factory of the Garford Company, manufacturers of automobiles at Elyria, O. Not all of the gas produced is used for producing power; but some summaries are given which show that the total cost of the fuel gas is about 33 cents per equivalent of 1000 feet of natural gas, coal being at $2.20 per ton delivered. Under these conditions, the total unit cost for the output of the electrical power plant, which consists of three 130-kw. 225 rev. per min. direct-current machines, is 2.45 cents per kilowatt-hour, of which 1.2 cent are charged to operating costs. The load factor is low, the output being 525,000 kw-hrs. per year corresponding to a factor of about 18 based on two machines only.

"Chart for the Calculations of Size of Conductors for Transmission Lines," L. A. Herdt.

A variation from the ordinary way of using the well-known Mershon chart.

[*Engineering Magazine,* December.]

"The Economy of the Individual Motor Drive for Machine Tools," H. S. Knowlton.

A careful and well-illustrated discussion of the economy of individual motor drives in factories, machine shops and similar situations.

[*Power and the Engineer,* January 5.]

"An Extensive Power Plant in the South," Cecil P. Poole.

A description of the extensive properties of the Southern Power Company, liberally illustrated and provided with maps and plans. The company's ten-hour load is now about 50,000 h.p.

"New Turbine Plant at Allentown, Pa.," John I. Baker.

An article describing a steam turbine 8000-kw. alternating-current plant whose feature of special interest is the coal and ash handling lay-out.

News Notes

Dossert & Company, 242 West 41st Street, New York City, have received orders from the United Electric Light & Power Company, of New York City, for a large number of solderless connectors for use in the 146th Street substation, including elbows for connecting ingoing and outgoing solid buses through oil switches, lugs for connecting solid round to flat buses, special lugs on remote control switches and special two-way studs tapping from No. 0000 solid rod direct to buses. The Pacific Gas & Electric Company, San Francisco, Cal., have also placed an order with the company for a large assortment of cable taps, front connected lugs, swivel lugs and angle lugs.

The Phoenix Glass Company of New York, Pittsburg and Chicago, has retained the Bureau of Illuminating Engineering, 437 Fifth Avenue, N. Y., to act as consulting and designing illuminating engineers, in the matter of designing or redesigning glass globes and reflectors, as manufactured by them, so that beauty and utility will be sensibly blended. Mr. Albert J. Marshall, Chief Engineer of the Bureau, will have direct supervision of this work.

The Blackburn-Smith Feed Water Filter and Grease Extractor has been chosen for the new Colliers, Mars, Hector and Vulcan, now being built for the U. S. Navy by the Maryland Steel Co. These ships have the highest class of equipment, and every possible protection. The filters are to be placed in the feed lines, so that every drop of water entering the boilers is subjected to the double filtration, characteristic of the Blackburn-Smith Filter. It is figured that by removing the oil and grease particles from the condensation, the filters will repay their cost in a short time by decreasing boiler repairs and increasing fuel economy. These filters are also excellent for protecting the boiler of stationary plants from floating particles of oil, grease, mud, etc., in the feed water. They are made by James Beggs & Co., 109 Liberty St., New York, who are distributing an interesting booklet on Feed Water Filtration.

George C. Smith, an executive officer and director in many auxiliary Westinghouse companies, has been appointed by the new board of directors of the Westinghouse Electric & Manufacturing Co. as its special representative in connection with its interests in a large number of electric railway and electric power companies whose securities are held as investments.

Among the companies are the Lackawanna & Wyoming Rapid Transit Co. and subsidiary companies, Niagara, Lockport & Ontario Power Co., Electric Power Securities Co. of Niagara Falls, Grand Rapids, Grand Haven & Muskegon Railway Co. and Atlanta Water & Electric Power Co.

Mr. Smith's headquarters will be in the City Investment building, New York.

The Allis-Chalmers Co. recently filled a train of 14 cars with the water end only of two huge vertical triple-expansion pumps, one purchased by the City of Chicago for installation in its Lakeview pumping station, and the other by the San Antonio Water Company, of San Antonio, Texas, as an addition to its present equipment.

The pump for the City of Chicago is of the vertical, triple-expansion type, as above noted, having three single-acting direct-flow pumps, equipped with automatic valves and provided with a flywheel. The engine is entirely self-contained in the pump chambers. This unit is guaranteed to develop a duty of 155,000,000 foot-pounds of work delivered to the pump for each 1,000,000 B.t.u. used by the engine and auxiliaries when pumping continuously at the rate of 25,000,000 gallons in 24 hours against a total head of 140 feet.

The San Antonio pump is practically a duplicate of the Chicago one. The normal and economical rating will be 20,000,000 gallons in 24 hours, but the Allis-Chalmers Company guarantees the unit to furnish 24,000,000 gallons in 24 hours to meet any excessive demands for water, as in the case of fire or extremely hot weather, without unduly straining either engine or pump.

The Allis-Chalmers Company claims to have built the first vertical, triple-expansion pumping engine for water-works service in any country, some 25 years ago, which is still running, and it is said that the world's record for economy is held by a pump of the same make and type.

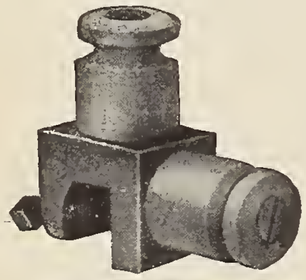
New orders at the shops of the Westinghouse Electric & Manufacturing Company, turned in recently, according to reports from Pittsburg, were with the railway department, including one for the equipment of 200 cars for the Third Avenue Railroad Company of this city, with a large amount of power house apparatus, representing an expenditure approximating $500,000. Another contract of importance taken by the Westinghouse people was an order for fifty-five mining locomotives from the Clinchfield Coal & Coke Company of Clinchfield, W. Va., to be used for the transportation of coal in that company's mines. The East Pittsburgh shops are also busy with the construction of a quantity of electric railway apparatus for the Spokane & Inland Railway Company of Spokane, Wash., to be used in the extension of that company's single-phase system; while two 4000-h.p. water wheel generators are being furnished to the Southern Power Company of Charlotte, N. C.

Warren Webster & Company, of Camden, N. J., announce that the

business heretofore carried on by the American Engineering Specialty Co. with headquarters at Chicago, and branches and agents in various cities of the Middle West, will be conducted in the name of Warren, Webster & Co. This change will give to architects, engineers, contractors, users and intending purchasers of "Webster" apparatus the full advantages of the company's organization, which now covers all parts of the country.

Universal Insulator Supports

It has long been a well-recognized fact that the most difficult part of a wiring job in steel frame mill and factory buildings has been the devising, making and erecting of all manner of special work for securing the insulators on which the wiring is to be supported. This work has to be done by the most skilled and experienced man available or laid out by a competent draughtsman. It is expensive in any event, and it is seldom that two jobs are done in anything like the same way, each individual having his own method. All this special work must be schemed out and completed before the actual work of wiring can be started. After the supports have been schemed out and the wire is up, it will be found that a great deal of wood has been used and probably a considerable number of holes drilled in the ironwork.



INSULATOR SUPPORT.

Wood introduces the element of danger from fire and dries out, allowing the supports to loosen. Holes weaken the ironwork, and in some cases might lower the safety factor to a dangerous extent. Wires are often changed from their original location when the special work becomes worthless scrap and new special work has to be devised.

It is needless to state that the cost of special work and the drilling of holes in iron is very costly, to say nothing of the loss occurring when special work must be scrapped. Universal Insulator Supports are cheap in first cost, do away entirely with special work, save time in the actual work of erection and are never scrap; but when taken down from one job go directly into stock ready for the next.

Where wire is to be supported from iron or steel fabrications, Universal Insulator Supports are all that the name implies—universal in application. They can be used in any position on the hangers of any rolled structural shape, beams, angles, channels, "Z" bars, round, square and flat bars, gas and water pipes, edges of tanks, plates, etc.

They are made of the best malleable iron and will stand rough use without breaking. They are light enough for light work and heavy enough to stand the strain of heavy work. The cup-pointed, hardened steel set screws hold them securely, and they will not loosen, even when subjected to the most severe vibration.

Personal

Mr. H. B. Thayer, president of the Western Electric Co., of New York, is making a short visit to Europe.

Mr. Walter J. Jones, who was associated with the late Dr. F. A. C. Perrine, will continue the firm's consulting engineering practice at the offices, 60 Wall St., New York.

Mr. G. E. Tripp, of Stone & Webster, of Boston, Mass., has been retained by the committee in charge of the affairs of the Metropolitan System of New York to make an examination of the property and formulate a plan for its reorganization.

Mr. E. T. Munger has severed his connection with the Metropolitan West Side Elevated Railway Co. of Chicago, where he was superintendent of motive power and equipment, to become general superintendent of the Hudson & Manhattan Railroad, operating under the Hudson River between New York and New Jersey.

Mr. E. G. Eager, of Toledo, Ohio, has been engaged by the Goodwin & Kintz Co., of Winsted, Conn., as their agent in the Philippines, Australasia and New Zealand. Mr. Eager is now in the Fiji Islands, and will be gone for a period of 18 months, during which time he will display to the buyers of those far-off countries the electroliers, portables and other electric lighting specialties made by Goodwin & Kintz.

Catalogue Notes

The Harrison Safety Boiler Works, of Philadelphia, have reprinted from "The Bookkeeper" a useful article on "Steam: Its Profitable Utilization," by Geo. H. Gibson.

The Wagner Electric Manufacturing Company, St. Louis, has issued their bulletin No. 82, giving a complete description of its line of polyphase motors. The bulletin is reenforced by a pamphlet on "The Polyphase Motor in a Shop," whose title explains its purpose.

The Wm. H. Colgan Company, of West Newton, Mass., has issued a catalogue describing the "Rex" line of outlet and switch boxes.

The Western Electric Company, of New York, has issued a bulletin describing and illustrating the new Roteau type of steam turbine which it has recently placed on the market.

The Fort Wayne Electric Works has gotten out a useful pamphlet entitled "A Practical Guide for Transformer Testing." The subject is explained with the aid of numerous diagrams and curves.

The Fort Wayne people also have sent out a bulletin describing their line of revolving field engine-driven alternators.

The Jeffrey Manufacturing Company, of Columbus, Ohio, has sent out its catalogue 67D, describing the Jeffrey line of "Rubber Belt Conveying Machinery." The catalogue is profusely illustrated with photographs of numerous installations of this type of machinery and the parts necessary for their maintenance.

The engineering department of the National Electric Lamp Association has issued bulletin No. 8, 35 pages, containing a complete list of the regular type of miniature carbon filament lamps for decorative effects, battery inspection, automobile, telephone and special service.

The General Electric Company has issued its Fan Motor Catalogue for 1909, containing illustrations, description and prices of the company's entire line of fan motors for the coming season. The list comprises alternating and direct-current fan motors for desk, bracket, ceiling, floor column and counter column fans in various sizes together with their supply parts. The bulletin also describes ventilating and miscellaneous small power motors for alternating and direct-current.

The General Electric Company has also issued the following bulletins:

No. 3715.—Describing mercury arc rectifiers for telephone battery charging.

No. 4633—Covering motor-generator sets and frequency changes.

No. 4628—Describing the G. E. mercury arc rectifier.

No. 4629—Devoted to all sorts of electrical accessories for automobiles.

No. 4626—Telling about the series luminous arc rectifier system.

No. 4631—Describing the series alternating enclosed arc lighting system.

No. 4630—Relating to type D. P. direct-current portable instruments.

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NOTICE TO ADVERTISERS

Insertion of new advertisements or changes of copy cannot be guaranteed for the following issue if received later than the 15th of each month.

Corporation Publicity

In the rapid changes during the last few years in the relations between the great corporations of the United States, and the great public in which they live and move and have their being, none has been more eagerly welcomed, or more pregnant with the brightest promise for the future than that which has taken place in the matter of publicity.

In place of the atmosphere of solemn mystery which pervaded many of the executive offices of the great public service companies, the seeker after information now finds a clear, frank attitude, a recognition of "the right to know," and a willingness to facilitate the acquisition of the knowledge that would stupefy many of the men who were in charge of these same properties 30 years ago.

It is, therefore, a wonder to many of us when now and then someone comes forth to seriously question the wisdom of the policy of publicity. More marvelous still, to see the heads of some of the largest concerns, of the kind under consideration, clinging to the dwindling company of those who are apparently afraid to submit their financial transactions to the light of day. Yet it is true that many reputations are being dimmed, and the results of years of usefulness are impaired by adherence to the old policy of concealment which has not merely survived its usefulness but become a stumbling and an offense.

It is a far cry from the corporation statements of 1880 to those of 1909. In contrast with the few obscure lines of those days—if indeed anything at all was issued—we take pleasure in placing such statements as have come out recently in a great number of instances.

We now see set forth the complete story of the financing, maintenance and operation of the properties. Full information is given as to bonds, stocks, notes payable, gross earnings, operating expenses, net earnings, fixed charges, net divisible income, dividends, and the whole array of useful record data of expenses and earnings per service unit or car-mile that so much facilitate the analysis and comprehension of a modern corporation's activity. With this information before him, he who will take the trouble may gather a fair knowledge of the actual facts that confront the management of the corporation, and many things that looked suspicious and arbitrary in the twilight of concealment become rational and reasonable when seen in the noonlight of confidence.

A great improvement is to be noted in the attitude of the people toward the corporations which have adopted the new methods. Evidences of it are everywhere. The tendency to foolish and ill-considered legislation regarding public service which has so often marred the record of various law-making bodies has subsided, the raucous note of the professional agitator—he of the sublime conviction of the innate vileness of the body corporate—has toned down. Less is heard from the noisy chorus of panacea-peddlers—doctrinaires who are willing and anxious to regulate anything in the heavens above, or the earth beneath, or the waters thereunder. A clearer, calmer, fairer view of affairs, a more rational tone of discussion of them is the tendency of the day, and it will continue.

It is true that publicity as now practised costs money. The preparation of special accounts and statements, the reprinting and dissemination of information, and, as has been done in many instances, the hiring of certified public accountants to verify the statements—all these and other incidental features total up a considerable expense. But a few of us still remember those other expenses that belonged to the pre-publicity era. There is no comparison.

Ask any wide awake corporation executive officer as to the financial returns on the money so invested—leaving aside its moral aspect—and he will probably tell you that it is one of the best investments his company has ever made.

The growth of the new feeling is based on the fundamental principle that the interests and prosperity of the corporations and the people they serve and the people who serve them, are one and the same. The gratitude of the industrial world is due to those who, having first grasped this principle themselves, have helped by precept and example to drive home the fact to the consciousness of all three classes.

New Transit Legislation

It is instructive to note that one of the most pressing duties with which the Public Service Commission of the First District of New York finds itself confronted is to secure amendments to some of the legislation that has been previously enacted. In the abstract of the report for the year just ended, on page 45 of this issue, we find no less than five such amendments asked for; and in addition to these, which refer to the Rapid Transit Act, a constitutional amendment is recommended providing for the exemption from the city's 10-per-cent. debt limit of bonds issued for the construction of self-supporting rapid transit lines.

To the uninitiated, it looks as if this is one more instance of the wisdom of being sure you're right before going ahead. As there is not the least doubt that any rapid transit line in New York City would be self-supporting if it was asked to earn a fair return solely on the money invested in construction and equipment, it would look but fair to provide for their financing—in the true sense of the word—without their coming on the city's permanent debt. Cannot this be done by arranging for the automatic retirement of the bonds from a sinking fund taken from the earnings? By this means the debt would in time cease to exist, and would encroach on no limits.

It is hoped that other communities than New York (whose excuse for desperate legislation is the desperate needs of her case) will take warning, and give to their public service laws the amount of cool and careful judgment demanded by the importance of the subject.

The Ultimate Factor

"The laborer is worthy of his hire."
—St. Luke, 10:7

Since the dawn of modern industrialism, the highest inventive genius, the greatest technical skill have been unwearied in the effort to improve processes and in perfecting machinery. Millions of dollars' worth of apparatus have been sent to the scrap pile in a condition almost as good as new because some new turn in the design or combination of processes has developed something else that would do the work a little better or a little faster. Other millions have been freely expended on experiments, in the hope that they would lead the way to improvement of the work that the industrial unit is devoted to turning out. Tireless patience, and limitless human nerve-energy, have been lavished on the machine and on the processes wrested from reluctant nature.

Yet by some strange mischance the most important factor in the whole scheme of industrial affairs has been comparatively neglected until quite recently. We refer to the *man*—to adapt a phrase from warfare (and competitive industrialism is warfare) —we may call him "the man behind the machine." Cruel in many ways has been the bearing of the machine on the life of the man who is its partner in production. From the old position of the independent craftsman, proud of himself, his station and his craft, he has seen himself descend little by little, forced by the pitiless processes of specialization into the place of a mere machine-part, the bound attendant to an inanimate steel thing. From a knowledge of all the details of his work, and an intimate, almost equal relation with the head of the business, his outlook has been narrowed to the knowledge of a petty part, he has become almost a nameless unit among the toiling hosts of the mill and factory, far off and personally unknown to those whose wealth his toil helps to create.

To-day we see signs of a change in all this. The captains of the industrial armies are at last waking to the realization of the facts. After spending the millions on the machine-part to get from it the last point of efficiency, they are finding that the place for the profitable placing of those same millions is on the human-part. The last few years have seen the beginning of the change in the scene; slowly, but surely, it has dawned on the brightest minds that the man behind the machine is the most alluring field for the future improvement in industry. A whole new science, based on principles sound not only industrially but *morally*, has grown up. The result of this has been the developing of the new methods of wage paying, as well as the new feeling of responsibility for the employee. The outcome of these efforts, which are based on an appeal to all that is best in both employer and employee, has been fruitful beyond all the dreams of their projectors. We hear of outputs running 25 to 40 per cent. above those previously obtained, simply by the introduction of the bonus system. Net earnings of companies wise enough to grasp the great principle involved and apply the methods have increased in even greater ratio. And, best of all, the worker is benefited materially and morally. His individuality is awakened, he comes to realize himself, to know his own worth and the knowledge spurs his ambition, his energy and his self-respect.

This magazine reaches the hands of thousands of both classes—the employer and the employee. The lot of the latter in the great electrical factories and power plants, the railways and countless other industries that have been born of, or quickened by the growth of electrical processes, has been in no whit different from that of his fellow-workman elsewhere. It is with pleasure, therefore, that we direct the attention of our readers to the article in the current issue describing the training school of the power department of a great hotel, whose management has been foresighted enough to devise a comprehensive plan for the improvement of its working force and at the same time to materially decrease its operating expenses.

Just what importance these decreases amount to in the plant may be realized when we state that the saving in the cost of the boiler horsepower, due in part to the effects of the bonus system on improving the firing, amounted to at least $5,000.00 during the year just ended.

Estimating the annual coal bill for power plants in New York alone at $30,000,000, a similar economy would mean a saving to plant owners of this city of more than $6,000,000, and this is only the material side of this question, and is based on what has actually been done.

We believe that the details by which such results have been brought about have a direct bearing on a subject whose importance cannot easily be overestimated. For, after all, the man is the ultimate factor in all human activities and it is from him, in the firing-room as well as in the office, that the further improvements in the mass of modern industrial achievement must come.

Water-Power Control

In a message to the House of Representatives, accompanying the veto of a bill to permit the construction of a dam across the James River, in Missouri, for the diversion of its waters for electrical power purposes, President Roosevelt takes occasion to warn Congress that the control of the available water-powers of the country is being acquired by a few powerful interests, without any regulating or limiting conditions, thereby threatening the well-being of the public. In part his message says:

> The people of the country are threatened by a monopoly far more powerful, because in far closer touch with their domestic and industrial life, than anything known to our experience. A single generation will see the exhaustion of our natural resources of oil and gas, and such a rise in the price of coal as will make the price of electrically-generated water power a controlling factor in transportation, in manufacturing and household lighting and heating. Our water power alone if fully developed and wisely used is probably sufficient for our present transportation, industrial, municipal and domestic needs. Most of it is undeveloped and is still in national or State control.
>
> To give away without conditions this, one of the greatest of our resources, would be an act of folly. If we are guilty of it our children will be forced to pay an annual return upon a capitalization based upon the highest prices which the "traffic will bear." They will find themselves face to face with powerful interests intrenched behind the doctrine of "vested rights" and strengthened by every defense which money can buy and the ingenuity of able corporation lawyers can devise. Long before that time they may, and very probably will, have become a consolidated interest controlled from the great financial centers dictating the terms upon which the citizen can conduct his business or earn his livelihood and not amenable to the wholesome check of local opinion.
>
> The total water power now in use by power plants in the United States is estimated by the Bureau of the Census and the Geological Survey as 5,300,000 horsepower. Information collected by the Bureau of Corporations shows that thirteen large concerns, of which the General Electric Company and the Westinghouse Electric and Manufacturing Company are most important, now hold water-power installations and advantageous power sites aggregating about 1,046,000 horsepower, where the control by these concerns is practically admitted. This is a quantity equal to over 19 per cent. of the total now in use.
>
> Further evidence of a very strong nature as to additional intercorporate relations furnished by the bureau leads me to the conclusion that this total should be increased to 24 per cent.; and still other evidence, though less conclusive, nevertheless affords reasonable ground for enlarging this estimate by 9 per cent. additional.
>
> In other words, it is probable that these thirteen concerns, directly or indirectly, control developed water power and advantageous power sites equal to more than 33 per cent. of the total water power now in use.

Having thus sounded the alarm in characteristic fashion, the President presents his views as to the proper preventive, repeating the words with

which he concluded his message vetoing the Rainey River bill, as follows:

In place of the present haphazard policy of permanently alienating valuable public property we should substitute a definite policy along the following lines:

First—There should be a limited or carefully guarded grant in the nature of an option or opportunity afforded within a reasonable time for development of plans and for execution of the project.

Second—Such a grant or concession should be accompanied in the act making the grant by a provision expressly making it the duty of a designated official to annul the grant if the work is not begun or plans are not carried out in accordance with the authority granted.

Third—It should also be the duty of some designated official to see to it that in approving the plans the maximum development of the navigations and power is assured, or at least that in making the plans these may not be so developed as ultimately to interfere with the better utilization of the water or complete development of the power.

Fourth—There should be a license fee or charge which, though small or nominal at the outset, can, in the future, be adjusted so as to secure a control in the interest of the public.

Fifth—Provision should be made for the termination of the grant or privilege at a definite time, leaving to future generations the power or authority to renew or extend the concessions in accordance with the conditions which may prevail at that time.

Sixth—The license should be forfeited upon proof that the licensee has joined in any conspiracy or unlawful combination in restraint of trade, as is provided for grants of coal lands in Alaska by the act of May, 28, 1908.

He closes by asserting that he will sign no bills granting privileges of this character that does not contain the substance of these conditions. Moreover, he promises to insist upon the observance of these same provisions in passing upon plans for the use of water-powers presented to the executive departments for action.

It would be instructive to know whether the statements made referring to the General Electric and Westinghouse Company's water-power holdings, which are based on a report by his Commissioner of Corporations, Herbert Knox Smith, are absolutely true. On the same date that the message was issued one of the officers of the General Electric Company risked a nomination to the famous Ananias Club by stating that so far as he knew, the only water-power transmission property that the General Electric Company controlled was the modest one supplying energy to the works at Schenectady.

The general impression regarding the facts of the situation is that the President has somewhat overstated the case. The usual plan of financing hydro-electric projects, which, except in very favorable instances, call for a large investment long before their income attains its growth, has been to induce the manufacturers supplying the expensive machinery to take at least a part of their payment in bonds. When the manufacturing companies have done this it of course remains optional with them to either sell the bond to some of the numerous bond houses that handle this sort of business, or hold them for the benefit of their expected income. Judging from the large number of water-power companies that are now in the hands of receivers, it would seem a sound policy to have let go of such bonds whenever they could be disposed of on reasonable terms. This is what we understand has usually been done.

But, laying aside the present aspects of the case and looking into the future, the President is right in his contentions. A far-sighted, comprehensive policy in this matter will be of immeasurable benefit to those who come after us upon the land. And it is no minor matter that is involved. The dower of this country in water-power, while relatively less than that of Norway or Switzerland, is, in the aggregate, of imperial proportions—more so than would appear from the figures mentioned above. Competent authorities have compiled a table as follows:

FOR THE UNITED STATES

		Value of annual income (At $35, per hp. per year)
Developed horsepower	5,300,000	$185,000,000
Undeveloped horsepower	8,100,000	350,000,000

Location.	
New England	600,000
New York, Pa. and Middle States	1,650,000
Southern States	4,000,000
Northern and Western States	1,050,000
Pacific Coast	800,000

These figures are based on minimum flow calculations. A reasonable estimate of the total available water-power assets of the United States is 20,000,000 h.p., corresponding to a consumption of 300,000,000 of coal annually. This is equal to about 90 per cent. of the entire estimated production of soft coal for 1908. The value of the annual income, under the above assumption, would be five per cent. on $14,000,000,000!

It seems to us that the public control of this form of energy is peculiarly fitting. For its beginnings are in the union of those ancient freeholds of the race—light and air.

From the far reaches of the shining sea, the mighty energy of the sun draws up the countless atoms of water-vapor. Carried by the great air currents that are impelled by the same radiant force that raised them up from the ocean, the vapors are borne across a thousand miles of land and sea until one day as snow or rain they fall upon an upland. Out of a thousand fountains gush the waters to form the hurrying mountain stream. By many a winding path, past rock and bar the waters twist and turn, until, by union with other streamlets, grown to the dignity of a river, they find their way barred by a solid wall. From the pool so formed they turn into a channeled way made by the hand of man, along the side of the hill. At the end of a few feet or miles they rush into the blackness of a steel tube, falling through tens or thousands of feet until the accumulated pressure has imparted an energy comparable with that of dynamite. Then they burst through a swinging door to light, relief and freedom once more.

The hinge of that door is the shaft of a water-wheel or turbine, and into this line of steel passes the sun-born air-carried power of the water, and thence to the circuits of a generator, in the shape of electricity. From here it darts mechanical power, light, heat and comfort—and all of these are wealth—to the hearts of a hundred cities. And this goes on forever. So long as the sun shall draw the sea, and the winds shall blow, the power of the "white coal," as the French so aptly term it, shall minister to the wealth and well-being of the children of men, and men shall indeed be children if they let this rich gift of Nature slip from the control of the many into that of the few.

Re-Rating of Turbo-Generators

Now and then a rumor passes that some of the big public utilities companies are contemplating changing the rating of the large turbo-generators that have been in service long enough for the operating force to have a pretty good idea of what the machinery can do. Of course the "re-rating" will not make a bit of difference in the apparatus, but as it is understood that the units are operated on the bais of their factory ratings, if the re-rating is put into active operating effect the results may be of some value.

The early designers of the turbo-generators were in a very different position from these who developed the older type of large-capacity slow-speed units. The former built up their product bit by bit. Pioneers in the field, they could set their own standards and none could cast aspersions on them because of their failure to meet some existing performance. Thus, in comparatively few years, the familiar forms of the direct-current and alternating-current generators were evolved and their characteristics were developed, corrected and pushed to the high degree of efficiency that has made them worthy examples of the perfection and precision of modern electrical engineering methods.

With the turbine unit the case was

widely different. Like that other efficient entity—the Prussian people—the turbo-alternator grew up to its present estate under a tremendous competitive pressure. Every turbine machine that was placed on the market was in competition with the well-established slow-speed engine driven type. To live, the newcomer had not only to "make good," but to "make very good." And though efficiency was an important consideration, operating stability and endurance was still more important, and conservative engineers questioned the operating performance promised of the turbine unit much more than they did other advantages claimed for it.

The result of this atmosphere was that the turbo-generator designers were themselves forced to be as conservative as they might be. "Daring with caution" might have been their watchword—daring where necessary, cautious where possible.

As pointed out in a recent editorial, given a prime mover of ample force, the out-put of an electric generator depends on its capacity to endure high temperatures and radiate heat. At first sight, the ventilating question in a large turbo-alternator would look to be what it is—a serious one. Comparing, for instance, the radiating surfaces of the armature iron and copper in the two types of machinery of approximately the same rated output capacity. It will be noted that while each is, roughly speaking, an annular surface, the dimensions of what might be termed the "ventilating ring" in the two cases are approximately as follows:

	Diameter in feet					Total Area	
	Outside	Inside	Mean	Width	Depth	Sq. ft.	Sq. in.
Engine Unit....	40	32	36	4.5	4	1,945	279,980
Turbine Unit....	10	6	8	6.5	4	525	75,600

Comparing the amount of heat energy that has to be radiated across this area on the assumption that the armature copper and iron losses are the same—and this is nearly the case—we find that the dissipation on the turbine-alternator must be nearly four times greater than on the engine-driven unit.

Taking the full-load armature losses, both copper and iron at 52.7 kw., the square inches of total surface of the ventilating ring per watt radiated are therefore about 5.3 in the case of the slow-speed unit and only about 1.4 in the case of the turbine unit.

The permissible temperature limit in the armatures is approximately the same. Nearly the same kinds of insulating material are used. Yet the temperature rise in spite of the reduced available ventilating surface was approximately the same. The reason for this, of course, lies in the greater ventilating efficiency of the air-current of the turbine type.

The rush of air through the ventilating apertures that are obtained through the high-speed of the rotor compares with the ventilating current of the older machine as a hand-fan with an electric-fan. The difference in results, so far as concerns ventilation, will illustrate the enormous cooling capacity of the air blast and the superior efficiency of high-speed methods in cooling, as well as in the generation of energy.

It has been well established by overload tests that the average turbine-generator could carry 25 to 50 per cent. overload with no higher rise in operating temperatures than a well-designed slow-speed unit would give. If the full-load temperature rise was 35 degrees, then 50 per cent. overload might be carried with 50 degrees rise.

The ventilation bogie being laid, the "burden of proof" in the argument becomes shifted to the steam end, and here we think lies the real reason for the tendency to raise the normal rating. As is well known, the deflection of the efficiency curves of the engine and turbine are very different on the overload portions of the scale. The engine curve turns "down" somewhat about the full-rated load. The turbine curve turns "up."

Therefore the economy of the turbine is greater with overload; that of the engine is less.

The water rates on a certain 5000-kw. turbine unit at full load and at 50 per cent. overload are 17.2 and 16.8 lbs. per kilowatt-hour, respectively, while on a 5000-kw. reciprocating unit operating under the same conditions of steam pressure and vacuum they are approximately 17.2 and 19 lbs.

Therefore, in the course of a year if the turbo-generator is carried at a larger load than the factory rating, appreciable operating economy will result. It is this inherent difference between the engine and the turbine that demands a difference in the ratings on the generator end. The value of the overload margin is materially diminished if the unit is able to carry an overload all the time. This consideration of the rating from an operating standpoint is the principal inducement for making the proposed change.

The disadvantage of the higher rating scheme lies in the fact the factor of safety in the insulation is decreased by approximately 15 degrees, where the increase in the rating is 50 per cent. From the manufacturer's standpoint, it was well to have these margins in connection with the guarantee under which the turbine is sold. Whether it was broader than necessary, time will tell. The performance of the great majority of turbine in use, in as far as regards burning out of insulation from overheating is concerned, has been so exceptionally good that it gives a fair reason for raising the allowable temperature limits.

The modern turbine-alternator has a field insulation that, in addition to being submitted to low-voltage strains only, is nearly absolutely fire-proof; and it is in the endurance of the armature insulation of the machines that are rated up and so operated that we must look for the answer as to the wisdom of the proposed step. It it results successfully it will be another economy in operating expenses and another triumph to add to the long list already credited to the turbo-alternator.

The Triumph of "Wireless"

The supreme test of the value of wireless telegraphy that came in the dark hours of the early morning of January 23d, when the White Star Line's *Republic* was rammed by the Italian Lloyd's *Florida*, seems to have at last brought home to the general public the real meaning of what "wireless" can and should do. Not only was the ship in touch with the shore within a few minutes after the accident, but it is actually claimed that had the *Florida* been equipped with a "wireless" outfit, the collision could not have occurred. The storage-battery also came in for its share of credit. It was due to it that the wireless plant was not put out of commission by the disabling of the electric plant which followed the impact of the *Florida's* nose into the vitals of the *Republic*.

As was to be expected, recognition of the lesson taught has been instantaneous and wide-spread. Already several bills have been introduced into various legislative bodies designed to make compulsory the equipment with the life-saving wireless of all vessels over a certain tonnage. It would appear that self-interest or self-preservation, which is said to be the first law of nature, would render such a bill superfluous. Nevertheless, we hope no more chance will be taken in the matter.

Sub-Stations

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THE use of the substation in a distributing system makes possible economies of investment and operation which cannot be realized without it, but it introduces a link between the generator and the consumer which adds to the complication of the system and its presence in a distributing system must therefore be amply justified by economic considerations.

The design of a substation building and equipment must be made with a view to economy of operation, facility of repair and construction work, security of the service and employees, and a minimum first cost consistent with these conditions, and with the importance of the service. Where growth is probable, due regard must be had for extensions of building or equipment, or both. The character of the building and equipment is fixed by the kind of service to be given, whether alternating or direct current, at high or low tension.

The economy of operation should be as high as possible as the added expense of maintaining an attendant must be offset by the superior efficiency of the substation system as compared with feeders direct from a generating station.

The arrangement of apparatus with regard to the work of construction and repair men will often save much in first cost and operation, not to mention the lives of the men. Proper provision for repairs will also shorten the time of a shut-down very materially, thus saving loss of income and injured reputation for reliability. No design is permissible which involves unusual risk of interruption to the service.

The first cost must be kept within proper limits since fixed charges on the investment form a considerable part of the cost of electricity supply and must be as low as possible.

Alternating-current substations are mostly of two kinds, viz., static transformer and frequency changing motor-generator.

Direct-current substations include synchronous converters, motor-generators, or storage batteries or combinations of these. In a few cases direct current has been distributed from a substation receiving its energy over a heavy low-tension trunk line from a direct-current generating station located on a river front or other favorable location. A battery auxiliary is usually employed where such an arrangement exists.

In alternating-current distribution transformer substations are used where the frequency of the distributing system is the same as that of the transmission lines, but voltage transformation is necessary. Such a substation consists essentially of incoming transmission lines, line or transformer switches, transformers, distributing switchboard, with feeder regulators, switches, instruments, etc., and outgoing feeders. In its simplest form it may embody but a single transformer and switches without instruments or other accessories, except perhaps lightning arresters, the pressure regulation being effected at the generating end of the line by the use of line drop compensators. Such an outfit does not necessarily require a building and may be used to supply a remote residence section where no large power service is required very satisfactorily up to 150 or 200 kw. Where the load is larger there is likely to be a demand for three-phase power, in which case three transformers may be supplied by a four-wire feeder, in a very inexpensive building without other accessories than disconnecting switches on each side of the transformers and lightning arresters. The four-wire transmission line may be regulated by regulators on each phase, at the generating end, and the distributing feeders carried to several adjacent suburbs. This system has been used for outlying suburbs in Chicago at 4400—7600 volts for loads up to 600 kw., power and lighting being served with the same degree of facility that is possible with similar business located within the range of the distributing feeders operating direct from the point of supply.

When the number of feeders from a substation is such that regulation must be secured at the substation, it is necessary to equip the feeders with potential regulators and maintain an operator on duty during the hours of heavy load. If there is much day power load an operator should be on duty about 16 hours a day as a rule. The addition of regulating equipment and an operator necessitates a higher grade of building, and this is usually warranted by the importance of the service at this stage of development.

The usual distributing voltage in alternating current systems being about 2300, a discussion of the elements entering into the composition of a transformer substation distributing at this pressure will serve to illustrate the principles of such a design.

A substation supplied by two transmission lines at 13,000 volts is to distribute energy by four outgoing three-phase four-wire 2300-4000-volt feeders through six single-phase step-down transformers of 400 kw. each. Local conditions, such as the available floor space, usually forbid an ideal layout, but as no two locations are alike, the arrangement of apparatus will be discussed from the standpoint of ample space being available for any desired arrangement.

The most desirable layout is one in which the progress of the flow of energy is continuous from incoming lines to outgoing feeders, and the connections and arrangement of apparatus should be made with this in view. Such an arrangement is illustrated diagramatically in Fig. 1 and in plan and elevation in Figs. 2 and 3.

The arrangement of Fig. 1 provides a switch for each incoming line and a tie switch between them, so that the lines may be used interchangeably, to supply one or both sets of transformers. Each transformer is provided with a switch on each side so that it can be disconnected for repairs or cleaning, and to enable it to be easily isolated in case of trouble in the transformer. The transformers feed into a common 2300-4000 volt bus, from which all feeders are supplied. An auxiliary bus should also be provided to facilitate construction or repair work around the board, and perhaps to permit the load of certain feeders to be carried on a separate line at higher pressure, or from a different source of power, over one of the lines. The use of an auxiliary bus requires double-throw switches throughout on the distributing bus and adds to the first cost of the station. It may therefore be omitted in small substations where there is a single incoming line and little justification for its installation.

The outgoing feeders leave the bus through single-pole switches and pass through the regulators for the control of the pressure.

The arrangement of the apparatus might be carried out as in the floor plan of Fig. 2.

The line and high tension transformer switches occupy space next to the wall with an aisle between them and the transformers of such width as to permit ready access for inspection, repairs or the replacement of a transformer. The 2300-volt switches are of the hand-operated type, and are mounted on the switchboard with the instruments. The 2300 volt buses are at the rear of the board with an aisle between them and the regulators, so that they may be accessible. The regulators are motor-operated and are placed near the wall in the path of the outgoing feeders. The control switches for the regulator motors are on the switchboard close to the voltmeter so that the operator may control the pressure while watching the voltmeter. Less expensive hand-controlled regulators may be installed, but these require the operator to go to the regulator each time regulation is necessary. This, of course, takes him away from the voltmeter while he is doing so, and does not permit of first-class operation. In small substations the hand operated regulators may sometimes be arranged with the controlling handles extended through to the front of the board, thus enabling the operator to watch the meters while regulating. With hand-operated regulators the space required by the regulators of a feeder being more than the width of a panel, the use of two rows of regulators with a staggered arrangement may be necessary. The connecting rods running to the front of the board obstruct the space at the rear of the board and are objectionable in a substation of the size of the one under discussion.

The elevation in Fig. 3 shows the disposition of the apparatus and cables looking endwise. The high-tension incoming lines enter the building through a duct line and pass to the compartment switches, transformer switches and transformers through cable connections protected at their terminals by insulating bells. The outgoing lines are handled in a similar way. The cables carried across the ceiling of the basement are mounted on suitable insulating supports, covered with varnished cambric insulation, and in case there is moisture present continuously they are lead sheathed. The expense of the basement excavation may be saved in case there is no special use for the space other than making the connections between the apparatus. In this case lead-covered cables may be laid in shallow trenches in the floor, with split tile protection, and the compartment switch is raised above the floor to permit connection to be made from the trench below.

The arrangement suggested in Figs. 1, 2 and 3 is of course an ideal one, since no limitation of space or other local conditions are imposed. In many cases the required floor space is not available or is too valuable for other purposes to justify its use for substation purposes. Under such circumstances floor space may be economized by placing the pressure regulators on a gallery above the switchboard, or in the basement. The latter arrangement brings them in line with the outgoing feeders and is preferable if the basement is of suitable depth and size to give room to handle and install the apparatus. With a room which is not long enough to permit the transformers to be set in a row, it may be necessary to try various groupings of the oil switches and transformers, until the best arrangement is found. This is conveniently done by laying out the space to a suitable scale and cutting out pieces of paper to represent the various pieces of apparatus to the same scale. The different arrangements may thus be laid down without the tedious work of making several drawings at considerable expense. Each proposed arrangement must be considered with reference to the disposition of the apparatus and connections in the basement as well as on the main floor. A design is not justifiable which makes a nice appearing installation of the main floor, but necessitates dangerous conditions elsewhere in the building.

The switches on the incoming line must be capable of opening the entire load under emergency conditions and should therefore be of the oil break type with separate fireproof compartments for each pole. These switches must be equipped for protection by reverse current relays, if the incoming lines are operated in parallel, which necessitates a set of current transformers on each line. Suitable space must be provided for these near the switch as well as for the relays.

The switches must be operated by alternating current with auxiliary

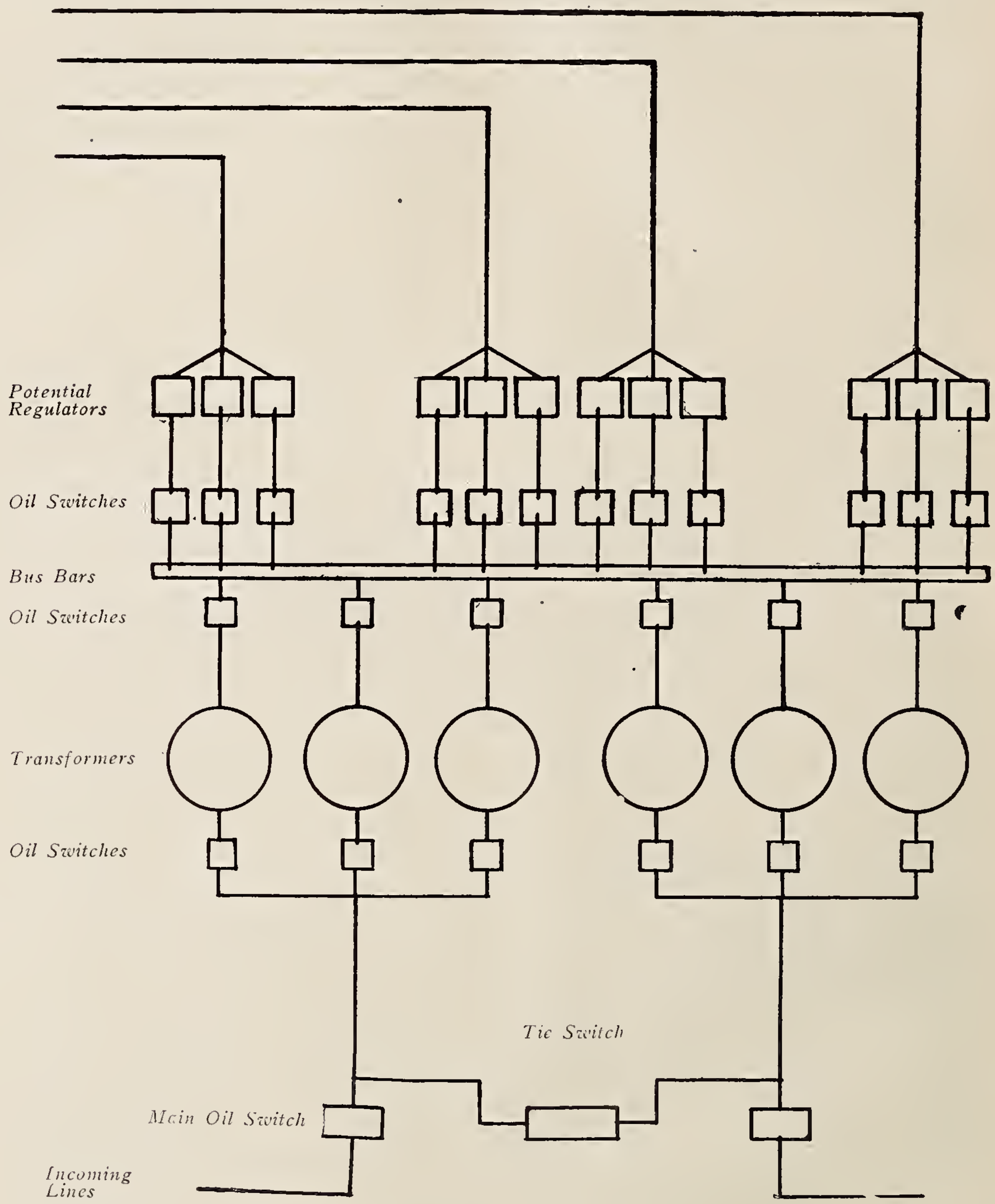


Fig. 1.—DIAGRAM OF SUBSTATION

hand control in the absence of any source of direct current for this purpose. The switches controlling the transformers may be of a smaller type of oil switch, the transformers being arranged so that they can be disconnected separately on both sides. The type of switch is that in which the

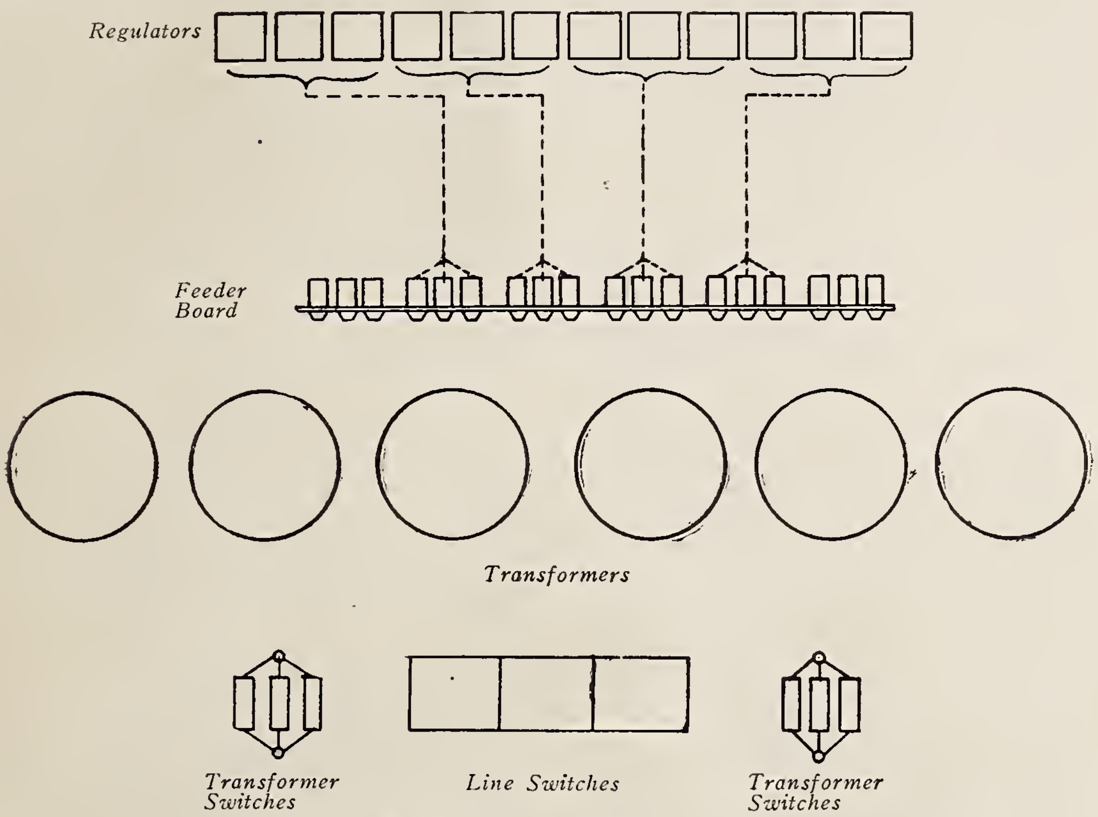


Fig. 2.—PLAN OF SUBSTATION

switch members are enclosed in oil in a tank, there being a double-break single-pole switch for each unit. The switches on the line side should be protected by overload relays, while those on the 2300-volt bus should be protected by reverse current relays to guard against the failure of a transformer coil.

These switches may be of the type which is closed against a spring by hand and opens automatically when tripped by the relay. The relays for primary and secondary of the transformers may conveniently be located on the switchboard panel which carries the secondary switch. The current transformers may be disposed in convenient and safe places where they are convenient to the leads of the main transformers.

The switches on the outgoing four-wire feeders should be single-pole and preferably equipped with the spring-actuated type of circuit breaker. Fuse protection is sometimes used on 2300-volt feeders, but it is not as satisfactory as circuit breakers, because of the longer time required to restore the service when a fuse blows, the greater likelihood of fuses blowing unnecessarily under heavy loads, and the difficulty of designing a fuse block which will not be injured by the operation of the fuse within a comparatively short time.

Four-wire three-phase feeders should not be controlled by three-pole switches as the neutral wire makes each phase virtually a separate feeder for all lighting or single-phase load and it is undesirable to interrupt the service on other phases because of trouble on any one.

Two-phase feeders should be controlled by separate switches on each phase for the same reason.

In the three-phase three-wire system where the load is delta connected, the opening of either phase interrupts the service on two phases, and the use of three pole switches is not so objectionable.

Outgoing feeder switches should have a maximum capacity for 150 amperes on the four-wire two-phase or three-phase system and 200 amperes on three-wire two-phase or three-phase system in order to permit an economical feeder load to be carried.

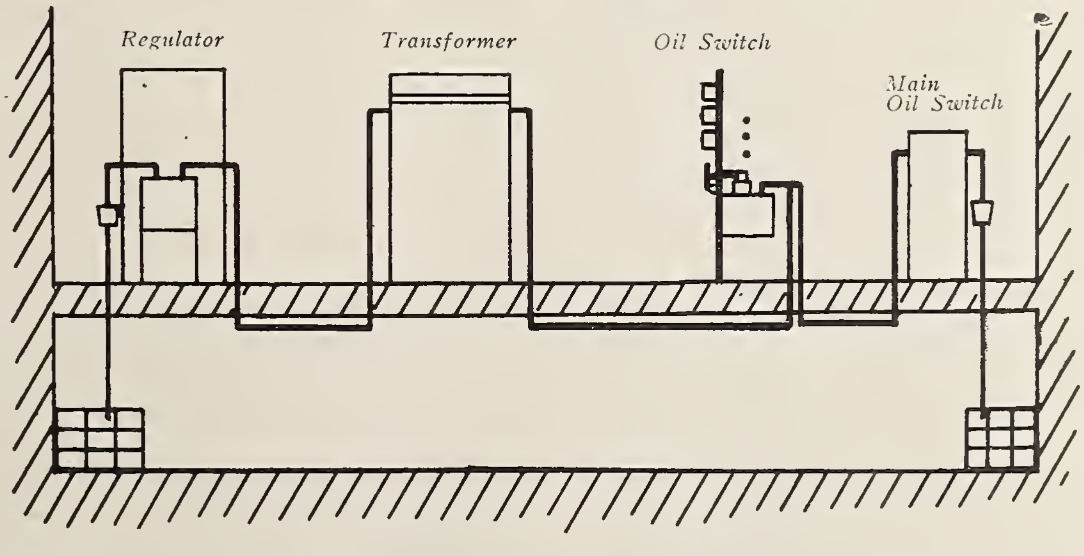


Fig. 3.—CROSS-SECTIONAL ELEVATION OF SUBSTATION

The layout of Fig. 3 is based on the use of oil-cooled and insulated transformers, this type being best suited to the conditions where space is not a consideration and where continuous attendance is not necessary.

Where floor space is a governing factor, the air-cooled type has decided advantages, as it is commonly designed to occupy a rectangular floor space which permits a very compact arrangement as compared with an equal capacity in oil or water-cooled transformers. The more rapid dissipation of heat in the air-cooled type allows a less expensive design. The presence of the blower, however, makes necessary some provision for space for its installation, and for the air ducts from blower to transformer. The usual arrangement is one in which air pressure is maintained in a chamber in a basement below the transformers, the heated air being discharged through openings in the case of the transformers into the substation.

With a four-wire three-phase system the transformers should be single-phase units, as the load may be unbalanced at times and the occurrence of trouble on one phase need not interfere with the operation of the other phases.

With a three-wire three-phase system so arranged that an entire feeder goes out in case of trouble, the likelihood of a considerable unbalance is small and the advantages of the three-phase transformer may be secured. This sometimes requires the use of an air blast, but makes a great saving in floor space.

With oil-cooled units of about 500 kw. and upward, it is often considered advisable to provide drains to a sewer for the transformer oil, so that in case it should become ignited it could be drained off to assist in extinguishing the fire.

With very high voltage transmission systems it is usual to install the transformers in separate compart-

ments to guard against the spread of an arc or flames from burning oil to adjacent transformers. With units of 2000 kw. and larger this expense is often justified, in view of the importance of the service and the investment involved.

The selection of the size and number of units for a substation is a matter of great importance from both operating and investment standpoints.

The units should be large enough to give some reserve capacity, and numerous enough to leave a working capacity in case a unit fails.

In the three-phase station used here for illustration, the use of two units on each phase results in a reduction of 50 per cent. in capacity on one phase if a unit fails. If the units have a reserve capacity of 20 per cent., the load can still be carried by running one unit at about 50 per cent. overload until a spare unit is put in place of the defective one. Where the service is important a spare unit should be available at all time for emergencies. In a system with several substations, two or three sizes may be standardized, one of each being carried as reserve. The switchboard should be located in a position where the instruments may be readily observed by the operator, and at a sufficient distance from the wall to give reasonably good access for construction and repair work. It carries no high-tension connections except where the feeder switches are of the hand-operated type, in which case they are preferably mounted on the panel with the instruments. Where remote control switches are employed the switchboard carries only secondary low-pressure wiring, such as instrument connections, remote control circuits, compensator circuits and the like. Such a board may be located in any convenient part of the room where it is accessible to the operator, if considerations of space demand it. The operation of remote control switches should be indicated to the operator by pilot lamps of red and green on the operating board.

Each feeder should carry an ammeter as a means of indication of the load carried and a voltmeter in connection with a line drop compensator to indicate the feeder end pressure to the operator. A power factor indicator is a desirable accessory on the main bus.

The transformer panels must also be provided with ammeters and a bus voltmeter for each bus and phase. The remote control wiring for the primary switch of the transformer is also brought to the transformer panels.

The design of the switchboard must be carried out with a view to making as compact an arrangement of switching apparatus as is consistent with safety of installation and operation.

The arrangement of the wiring for instruments, relays and similar apparatus should be carefully made with a view to making it secure from failure, accessible for testing and repair work and neat in appearance. Where several wires are grouped on one or two panels, the use of terminal boards for testing and repair purposes is very desirable. These should be placed so that an instrument adjuster can get at them conveniently without disturbing the connections at the instrument terminals.

the generating equipment supplies 25 cycle electricity and the frequency of distribution is 60 cycles. There are other cases, however, where the transformation is made from 30 or 40 to 60 or 62 cycles.

The best form of frequency changing apparatus consists of a synchronous motor wound for the transmission voltage, direct connected to a 60-cycle generator wound for the distributing voltage. Where the transmission voltage is above 13,000, it is not practical to construct motors wound for the transmission voltage, and transform-

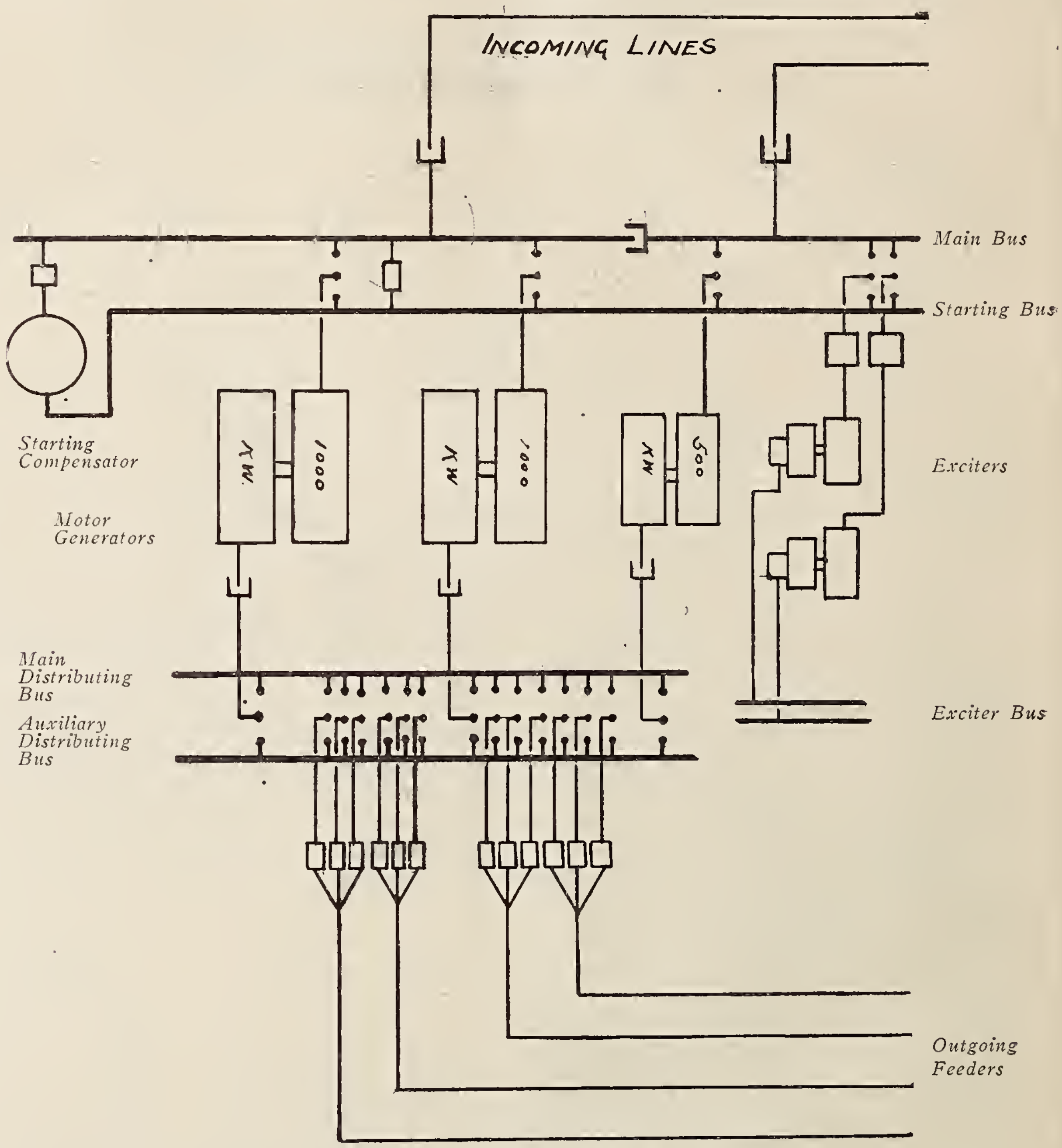


Fig 4.—PLAN OF MOTOR-GENERATOR SUBSTATION

ers are necessary. Greater stability and better efficiency may be secured by the use of induction motors, though this is offset in part by the lower power factor inherent to the induction motor.

The motor-generator outfit requires about the same floor space as an equal capacity in single-phase transformers when the two machines are mounted on a common bed plate with a short shaft and two bearings. When designed in the vertical form there is some saving in floor space in the larger units.

The essential difference between the

The switchboard should be of fireproof materials, marble and slate on angle iron frames, being the most commonly used construction. The arrangement of switches and bus connections should be such as to minimize the danger of the spread of an arc. The location should permit of necessary extensions which may be required in connection with the addition of feeders from year to year.

Frequency changing substations must be resorted to where the source of energy is operated at a different frequency from that of distribution. This condition is usually one where

frequency changing substation and a transformer substation is in the presence of motor-generators. The incoming lines with their high tension switching equipment and outgoing feeders with their switchboard and regulators are practically identical under equivalent conditions of load and space available in the two kinds of substations.

Where the transmission is at a pressure too high for the motor windings direct, the motor-generators require transformers and this increases the required floor space of the substation very materially.

With a substation of 2500-kw. capacity with synchronous motor generators taking energy at the line voltage, the units should consist of two 1000 kw. and one 500 kw. and the arrangement might be made similar to that shown in Fig. 4.

It will be noted that this substation includes exciters for the fields of the motor generators and a high-tension starting bus fed by a reactance coil, for use in bringing the synchronous motors up to speed, at reduced pressure. A single reactive coil is provided together with double-throw switches on the motors so that any motor can be thrown to the starting bus and started from the one starting coil, the extra cost of the bus and double-throw switches being less than that of the extra reactive coils. Duplicate exciters driven by separate motors at the transmission frequency should be provided as they must be started at times when the station is shut down, and reserve capacity must be available in case repairs become necessary on either unit. In some cases it may be sufficient to have two exciter units separately driven, with others driven by the main units. In the 2000-kw. vertical units in use in Chicago, the exciter is mounted on the shaft and is used interchangeably as a motor to start the unit from rest and then as a generator to excite its field poles. The supply of direct current for starting is drawn from the separately driven exciters. This reduces the shock on the transmission system experienced with starting from a coil, and results in a material saving in floor space which would otherwise be occupied by the exciter set.

Where the presence of direct current is taken advantage of for automobile charging, traveling crane or hoist service, it is important that the direct-current bus be divided so that the fluctuations of load will not affect the generator fields and so produce pressure variations throughout the entire system. Where a Tirrill regulator is used it is also desirable to have its operation control the pressure on the 60-cycle generators only, which necessitates the use of two direct-current buses.

It is also usually desirable in a substation having a number of feeders to provide two 60-cycle buses, so that certain longer feeders can be operated at higher pressure, and to permit the segregation of variable power load on separate machines where they do not affect the regulation of lighting pressure. It is desirable also as a means of facilitating repairs, as either bus can be cut off for repairs or construction work without interfering with the continuity of service.

The exciter units being less than 100 kw., it is usually not practicable to use motors wound for the line voltage. This requires a set of transformers but permits the use of comparatively low voltage induction motors which are less sensitive to shocks on the transmission system and permit the entire control of the exciter to be placed on a low voltage board.

and motor generators of different capacities are shown in Table 5.

Where motor-generator sets are employed, a selection must be made between induction and synchronous motors. The stability of the induction motor is balanced against the superior power factor of the synchronous motor, and (if the voltage of the transmission system will permit) the saving of transformers.

The presence of a considerable amount of distributed alternating-current load on other parts of a 60-cycle transmission system usually involves low power factors at the generating station. These may be largely compensated for by the use of synchronous motors in the direct-current substations, thus improving the generating conditions and increasing capacity to some extent.

The high-tension equipment of a direct current synchronous motor generator substation is very similar to that

EFFICIENCIES

KW.	25 Cycles				60 Cycles		
	Per cent. Load	Syn. Mot-Gen.	Ind. Mot-Gen.	Syn. Converter	Syn. Mot-Gen.	Ind. Mot-Gen.	Syn. Converter
300	100	84.	86.	89.5	86.7	85.5	88
300	75	82.5	84.5	88.7	85	83.2	86.8
300	50	78	80.2	87	81.7	79.5	82.5
500	100	85.5	87.2	90.8	87.8	87	89
500	75	83.7	85.5	90.3	86	85.5	87
500	50	79.5	83	88.5	83	82	84
1,000	100	87.5	87.8	91.8	88	87.8	90.5
1,000	75	86	86.5	90.5	86.5	86.2	88
1,000	50	82.2	84	89	84	82.8	86
2,000	100	88.2	88.8	92.3	88.6	85.5	....
2,000	75	86.8	87.2	91.8	86.7	86.5	....
2,000	50	82.7	84.5	90.5	83.5	83	....

APPROXIMATE COST PER KILOWATT

300	....	$26.25	$26.40	$25.30	$26.00	$26.10	$25.25
500	....	24.80	24.45	23.10	23.50	23.75	23.10
1,000	....	20.35	19.70	19.65	19.60	19.65	19.70
2,000	....	19.40	19.05	20.90	18.40	19.25	.....

FLOOR SPACE SQ. FT.

300	....	80	80	91	68	68	96
500	....	122	122	131	110	110	148
1,000	....	137	137	170	141	141	195
2,000	....	440	440	400	435	435	....

Fig. 5.—TABLES OF EFFICIENCIES, COST AND FLOOR SPACE

Direct-current substations may be equipped with motor generators, synchronous converters, or both.

With 25 cycles and other low frequencies, the performance of the converter not being hampered by any special difficulties, it is quite generally employed. With 60 cycles and other similar frequencies, the operation of converters is attended by some difficulties, such as "hunting" and flashing over, which, though remediable in many cases, have limited the use of converters at these frequencies. Synchronous and induction-motor generator sets have commonly been employed instead. The comparative efficiencies, size and cost of converters

above for an alternating-current substation. It is not necessary, however, in substations having several units to have facilities for starting from the alternating-current side on each unit. Direct-current starting methods are easier to manipulate, less expensive to install and make a smaller draft upon the system than alternating-current starting methods. The use of a double high-tension bus can be limited to one or two units.

The excitation system is, of course, provided for from the direct-current system without separately driven exciters, thus reducing the complication of equipment.

The direct-current distributing

equipment being operated at low potential is radically different from the 2300-volt alternating-current equipment above described. The bus bars may be of bare copper about half an inch thick and from three to six inches wide, and built up with air spaces between for radiation, to the required number, to carry the current. These are mounted at the back of the switchboard so that the connections to the generator and feeder switches may be as short as possible. The chief consideration in the design of such boards is an arrangement using a minimum length of copper, as it is necessarily of heavy cross section. The board should therefore be as short as possible and the opposite polarities should not be so close as to endanger the service in case a short circuit is made.

The arrangement shown in Fig. 6 accomplishes these objects very effectively. The upper row of switches are all of one polarity and the lower of another. The neutral conductor need not be switched and is connected direct to the neutral bus. The separation is ample and the length of bus-bar copper per feeder is about six inches for each pole of the bus.

This close spacing necessitates the use of the edgewise type of ammeter, an instrument being placed on each side of the three-wire feeder. The location of the polarities is usually standardized for the sake of uniformity. That is, the positive bus may be placed above or at the right, and the negative below or at the left, or vice versa. Separate voltmeters are not necessary for each feeder in direct-current networks, but the pressure wires brought from the feeder ends are terminated in a multiple point switch so arranged that the pressure on any feeder may be read on a single voltmeter successively. The bus pressure is usually indicated by a separate voltmeter, as this pressure should be visible to the operator at all times.

The individual regulation of feeder pressure is not feasible in direct-current systems, except for very long feeders which may be equipped with a booster set, or with very short feeders which may have a resistance in series to absorb part of the pressure.

Booster sets for use on three-wire feeders commonly consist of two generators of sufficient ampere capacity to carry the full load of the feeder, and voltage range sufficient to make up for the feeder loss, usually at least 40 to 50 volts. These are driven preferably by direct connection to a 230-volt motor of proper capacity. The booster generator fields must be designed to operate throughout the full range of pressure, without trouble at the brushes, and must have independent field rheostat control in order to permit compensation for drop on the neutral in case of unbalanced load. The location of a booster set should be such that the feeder cables will not require to be carried farther from their run than is necessary.

Feeder resistances are to be avoided as far as possible. Where necessary they must be of a design which will carry the feeder current and dissipate the heat generated without excessive temperature rise. Wire coils have been used for smaller feeders, but for those carrying 500 amperes and upward, strips of heavy galvanized sheet iron mounted on suitable insulating supports and surrounded with a wire netting for protection have given good results. There should be several sections of the resistance to permit the operator to make the necessary adjustment of pressure as the load and bus pressure vary at different hours.

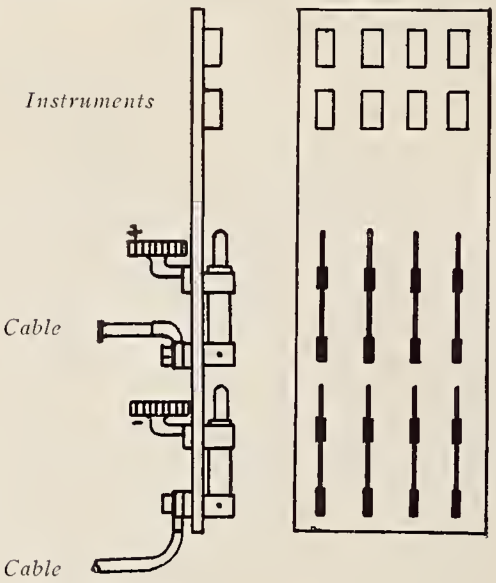


Fig. 6.—SWITCHBOARD

Rotary converter stations are similar to motor-generator stations as regards the direct-current equipment. The converter requires transformers and sometimes an air-blast equipment. The high tension switching equipment is very similar to that of other substations of equal size and importance. The starting of converter is accomplished preferably by the use of direct current, through a starting rheostat in series with the armature. This is usually arranged so that the rheostat is connected between the main bus and a starting bus. Each converter panel is provided with a starting bus switch through which any converter may be thrown to the starting bus and put into service by the use of one starting rheostat.

Facilities should also be provided for starting some of the machines from the alternating-current side, as this may be necessary in case of a general interruption of service in which the direct-current supply is removed. The arrangement of the apparatus varies with the character of the transformers and the means of pressure regulation.

With air-blast transformers an air chamber must be provided and the necessary blower equipment to produce a few ounces of pressure. If potential regulators are used on the converter these are mounted between the transformer and the machine so as to minimize the length of heavy leads. The regulator is connected without switches in many cases as there is little occasion to open these connections in operation. The regulators are usually remote controlled by means of a small motor with worm and wheel connection to the regulator. In recent practice the use of regulators has been obviated by the use of split-pole converters or booster converters for pressure control.

The split-pole converter permits regulation to be accomplished without loss of control of the power factor, by manipulation of the field strength. The different sections of the field poles are connected up separately to permit this.

The booster converter is a machine with a booster on the same shaft, so arranged that the pressure of the booster may be added to that of the converter or subtracted from it. The booster frame is cast with or bolted to that of the converter, so that no external wiring or bus work is needed. Little more floor space is required than for a standard converter, while the space occupied by a regulator is saved. This form of machine is somewhat more complex than the split pole converter but possesses some advantages which tend to offset this.

In connection with direct-current substations, it sometimes is desirable to maintain a storage battery reserve for emergency purposes and for use during the time of maximum load.

The most essential features of a battery station are ample space and proper ventilation.

The cells of the battery are set side by side so that the plates of neighboring cells can be joined together by a lead bar without the use of copper bus bar work. The floor space required by a battery is much more than that which is needed for converting apparatus of an equal capacity. It is sometimes necessary on this account to put part of a battery on another floor. The design of the building must, of course, be such as to support the weight, which is very great.

The use of sulphuric acid as an electrolyte, and the evolution of hydrogen, from the battery, tend to keep the air in a battery room heavily laden with sulphuric acid vapor. This acid corrodes all the common metals except lead and many organic substances. It is therefore necessary to protect all

structural steel work with building tile and plaster and to keep all copper bus work well painted. As a further means of reducing the severity of the action ample ventilation may be provided. Where natural ventilation cannot be secured fans must be provided discharging through a stock. During the summer months open windows may be relied upon where batteries are sufficiently remote from adjoining buildings to avoid interference with the rights of others. The floor of the battery room must be arranged to drain off any leakage of the electrolyte. The use of cement floors is not permissible on account of the action of the acid. It is therefore usual to lay a floor consisting of a layer of paper well coated with a roofing compound and over this a floor of vitrified tile brick with the spaces between the bricks carefully filled with compound. Such a floor will not permit the leakage of any electrolyte to lower floors, and is not affected materially by the acid.

The operation of the battery being affected by the specific gravity of the electrolyte, it is necessary to have a supply of pure water for the purpose of diluting the acid at intervals. The provision of facilities for the storage or manufacture of distilled water is therefore necessary.

The end cell connections are preferably terminated on an end cell switch built into one wall of the battery room. This keeps the strong acid fumes away from the end cell switch and other substation apparatus. The end cell switch is often so far from the operator that it is necessary to provide remote control apparatus for its operation. The end cell switch is commonly motor operated and indicating devices are provided to keep the operator informed as to its position.

The battery switchboard must be provided with two buses, to provide for discharge at two different bus pressures, in most cases. Edgewise type ammeters with zero point near the middle of the scale so that they can be used for charging and discharging are found most suitable in the main battery leads. The switchboard should carry a voltmeter to indicate the bus pressure of the battery, and another with a low scale to give the pressure on the individual end cells.

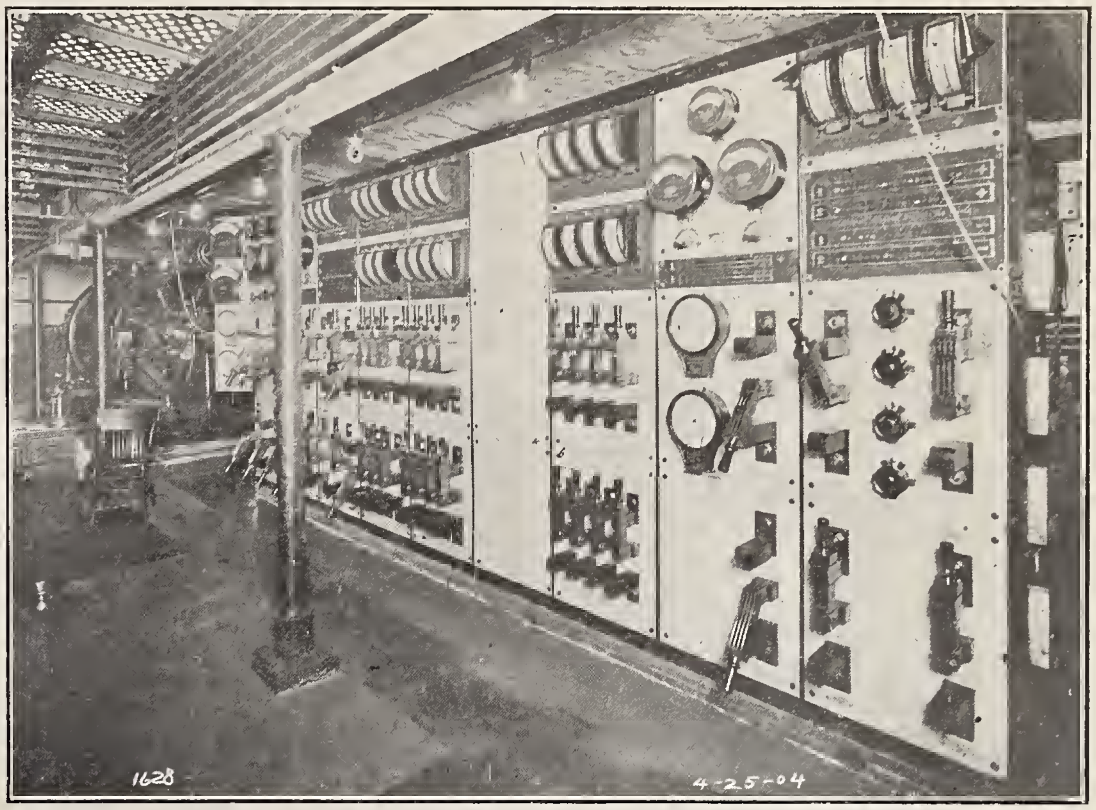


Fig. 8.—BATTERY BOARD WITH END-CELL SWITCH CONTROL

Fig. 7.—BACK OF SUBSTATION BOARD

Where rotary converters or motor-generators are available, it is preferable to have a machine wound to give a wider range of pressure for use in charging. This avoids the complication of booster sets, and is less expensive in first cost and operation.

In some cases, where space is difficult to get, it has been necessary to locate batteries in another building several hundred feet distant, extending the battery bus to the converter station bus through underground cables in the street. Such an arrangement is necessarily expensive and is only justified where the service is very important, as in a congested mercantile district.

The weight of a storage battery is such that it is usually impossible to place anywhere above the ground in a building not specially designed to carry it. This makes it usually impossible to put batteries and converters in the same building where all must rest on the ground.

A battery board with end-cell switch control is shown in Fig. 8.

Computing Boiler Power

CHARLES L. HUBBARD

THE following simple methods for calculating the size of boilers for heating, lighting and power purposes will be found convenient for quickly approximating the requirements in special cases where it is desired to obtain results quickly without the use of elaborate computations.

Calculations for power boilers are based on the steam consumption of the type of engines used, and vary even with the same type of engine, depending upon the size, speed, pressure and point of cut-off.

The following table may be used for estimating the steam consumption of different types of engines of first-class make and medium size. The last item, however, is for compound engines of larger sizes such as are met with in central station work:

Type of Engine	Pounds of Steam per indicated H.P. per hour	
	Non-Condensing	Condensing
Simple high speed	30 to 34	22 to 26
Simple medium speed	28 to 32	21 to 25
Simple Corliss	26 to 30	20 to 24
Compound high speed	24 to 28	18 to 22
Compound medium speed	23 to 27	17 to 21
Compound Corliss	22 to 26	16 to 20
Compound Corliss of over 500 horse power	20 to 24	14 to 18

TABLE I

After having estimated the weight of steam per hour for the type of engine to be supplied, it should be reduced to an equivalent evaporation from and at 212 degrees, and this result divided by 34.5 will give the required horse power of the boilers.

This change from the actual conditions of steam pressure and feed-water temperature to an "equivalent evaporation" is necessary because the latent heat of evaporation varies with the pressure, and the heat in the liquid varies both with the pressure and with the temperature of the feed water.

These facts make it necessary, when computing the power of a boiler or when comparing the efficiency of boilers working under different conditions, to reduce the results to a common standard. Table II is to be used in reducing actual results to this standard as illustrated in the following example:

EXAMPLE.—What boiler horse power will be required to supply steam at 140 lb. gauge pressure from feed water at 50 degrees temperature for a compound condensing medium-speed engine of 300 I.h.p.?

Taking the higher water rate from Table I for this type of engine, we have 21 x 300 = 6300 lb. of steam per hour. Looking in column one of Table II for a temperature of 50 degrees and following to the right until a steam pressure of 140 is reached we find the number 1, 21, which is called the "factor of evaporation" for these conditions, 6300 x 1.21 = 7623, which is the equivalent evaporation from and at 212 degrees, and 7623 ÷ 34.5 = 221, the boiler horse power required.

Temperature of Feed Water.	Steam Pressure by Gauge.											
	60	70	80	90	100	110	120	130	140	160	180	200
40	1.20	1.21	1.21	1.21	1.21	1.22	1.22	1.22	1.22	1.22	1.23	1.23
50	1.19	1.20	1.20	1.20	1.20	1.21	1.21	1.21	1.21	1.21	1.22	1.22
60	1.18	1.19	1.19	1.19	1.19	1.20	1.20	1.20	1.20	1.20	1.21	1.21
70	1.17	1.18	1.18	1.18	1.18	1.19	1.19	1.19	1.19	1.19	1.20	1.20
80	1.16	1.17	1.17	1.17	1.17	1.18	1.18	1.18	1.18	1.18	1.19	1.19
90	1.15	1.16	1.16	1.16	1.16	1.17	1.17	1.17	1.17	1.17	1.18	1.18
100	1.14	1.15	1.15	1.15	1.15	1.16	1.16	1.16	1.16	1.16	1.17	1.17

TABLE II

In the case of electric lighting the size or capacity of the dynamo is first obtained, and from that the indicated horse power of the engine, and then the boiler power as already described. There are different ways of doing this, depending upon the data at hand.

If the efficiency and candle power of the lamps are known, the total number of watts may be computed, from which the capacity of dynamo and power of engine are easily determined.

EXAMPLE.—A building is to have 700 incandescent lights requiring 50 watts each; 200 Meridian lamps requiring 60 watts each; 20 multiple arc lamps at four amperes each, and 10 at 7.5 amperes each. The system is to be supplied with a current of 110 volts. What will be the capacity of dynamo, horse power of engine and boiler horse power required? Assume efficiencies of 90 per cent. and 88 per cent. for dynamo and engine respectively, and neglect losses in the line.

From the data given, we have

700x50	= 35000	watts for incandescent lamps.
200x60	= 12000	" " Meridian "
20x 4x110	= 8800	" " small arc "
10x7.5x110	= 8250	" " large arc "
Total	64050	

64,050÷1000=64 kw., the required capacity of the dynamo.

Electrical energy in watts may be changed to horse power by dividing by 746, hence, 64,050÷746=86 horse power in the form of electrical energy to be supplied at the lamp terminals.

Horse power delivered to dynamo =86÷.90 (efficiency of dynamo)=96.

Indicated horse power of engine =96÷.88 (efficiency of engine)= 110.

Knowing the indicated horse power of the engine and the approximate water rate of the type to be used, the boiler horse power can be computed by the method already described.

Another way is to find the total current in amperes required by all of the lamps, then knowing the voltage at which they are to operate, the number of watts can be determined at once.

EXAMPLE.—What will be the required capacity of dynamo and power of engine to supply the current for a 110-volt parallel system, carrying 500 incandescent lamps at .6 amperes each; 100 similar lamps at 1.2 amperes each; 20 Cooper-Hewitt lamps at 3.0 amperes each, and 50 arc lamps at 5.0 amperes each?

$$
\begin{aligned}
500 \times 0.6 &= 300 \\
100 \times 1.2 &= 120 \\
20 \times 3.0 &= 60 \\
50 \times 5.0 &= 250 \\
\text{Total} \ldots\ldots &730 \text{ amperes.}
\end{aligned}
$$

730×110=80,300 watts, or 80.3 kw. 80,300÷746=108 h.p. to be delivered by the dynamo in the form of electrical energy, from which the indicated horse power of engine, and boiler power, can be computed as before.

Another method of getting the boiler power for electric lighting is by the use of Table III, in which it is assumed that one horse power of electrical energy will supply a certain number of lamps of different types as there given:

Number of lamps supplied by one horse power.	Type and power of lamp.
12	16-c. p. incandescent.
6	32-c. p. incandescent.
2.5	1200-c. p. arc.
1.7	2000-c. p. arc.

TABLE III

The efficiency of a first-class generating set (engine and dynamo), including the losses in transmission, may be taken as about 75 per cent. when located near or in the building to be lighted, so that the electric horse power necessary to supply the lamps divided by .75 will give the indicated horse power of the engine required.

EXAMPLE.—What boiler horse power will be required to furnish steam for a lighting plant carrying 2400 16-c-p. and 600 32-c-p. incandescent lamps, and 100 1200-c-p. arc lamps?

$$\begin{aligned} 2400 \div 12 &= 200 \\ 600 \div 6 &= 100 \\ 100 \div 2.4 &= 40 \\ \text{Total} \ldots\ldots &340 \end{aligned}$$

This is the horse power of electrical energy to be delivered by the rynamos. The indicated horse power of the engines is $340 \div .75 = 453$, from which the boiler horse power may be determined as before.

The steam required for operating a pump is found in a similar manner as for an engine, although they are rated in gallons of water delivered under given conditions, instead of horse power.

The weight of water in pounds per minute, multiplied by the height in feet to which it is raised, divided by 33,000, will give the useful or delivered work in horse power. The friction of the moving parts of a pump and of the water flowing through the passages and valves is so great that under ordinary working conditions not much more than 50 per cent. of the indicated horse power of the steam cylinders is utilized in doing useful work. This, together with the fact that steam is not used expansively, calls for a large amount of steam in proportion to the work done, as shown by Table IV, which gives the average steam consumption of the ordinary duplex pump:

Type of Pump	Pounds of steam per delivered horse power per hour.
Simple non-condensing.....	120
Compound non-condensing..	65
Triple non-condensing......	40
High duty non-condensing.	30

TABLE IV

In measuring the head against which a pump is working, take the vertical distance between the surface of the water in the suction reservoir and the highest point in the discharge pipe. If the pump is delivering against a pressure, as in feeding a boiler, reduce the pressure to "feet head" by dividing the pressure per square inch by 0.4.

The boiler power required for heating may be computed in several different ways.

In the case of new buildings it is customary to compute the total heat loss from the building in heat units in the coldest weather, by one of the numerous rules in common use for this purpose, and divide the result by 33,000. This gives the horse power necessary to evaporate the required amount of steam from and at 212 degrees, but the conditions of temperature and pressure are so similar to this in low-pressure heating that no correction is necessary.

Sometimes it is desired to install a boiler plant in a building where the radiation is already in place. In this case we may use the following relations between radiating surface and boiler power, assuming that one boiler horse power will supply 130 sq. ft. of direct cast-iron radiation, 100 sq. ft. of direct wrought-iron pipe coils, 50 sq. ft. of indirect cast-iron radiation, 20 sq. ft. of steam blast coils.

The boiler power computed in this manner should be increased about 10 per cent. to cover the loss by radiation from the steam mains and returns.

Large buildings containing their own power plant are often provided with a hot-water supply for various purposes. The boiler power for hot-water heating is easily computed if the quantity of water and its initial and final temperatures are known.

EXAMPLE.—What boiler horse power will be required to raise the temperature of 500 gal. of water per hour from 50 degrees to 180 degrees?

$500 \times 8.3 = 4150$ lb., and $180 - 50 = 130$ degrees rise in temperature, from which it is evident that $4150 \times 130 = 539{,}500$ heat units are required. This calls for $539{,}500 \div 33{,}000 = 16.3$ b.h.p. Placing this in the form of an equation we have:

$$\text{H. P.} = \frac{G \times 8.3 \times (T_2 - T_1)}{33{,}000},$$

in which

G=gallons of water to be heated per hour,

T_1=initial temperature,

T_2=final temperature.

When a building contains a power plant the exhaust steam is usually turned into the heating system; in this case the boiler power for supplying the engines and pumps is first computed and about 80 per cent. of this may be considered available in the exhaust for heating purposes.

If this is less than is required for heating in the coldest weather, additional boiler power must be provided to make up the deficiency. In designing a plant of any considerable size it is better to use several boilers of medium size rather than one or more very large ones, and it is also well to provide for a certain amount of reserve power so that part of the plant may be shut down for repairs or inspection without interfering with its operation.

In the Hands of a Receiver

The American Diesel Engine Company has filed a petition in bankruptcy. Adolphus Busch is the principal creditor, his claims amounting to $200,000. John D. Wilke was appointed receiver of the alleged bankrupt company by Judge Holt, with a bond of $50,000. He is authorized to continue the business for ten days. The assets of the corporation as described by the petitioning creditors consist of Diesel combustion oil engines, cash, accounts, and bills receivable, machinery, parts of engines, incompleted contracts for engines in course of construction, and personal property in the States of New York, Indiana, Wisconsin, Rhode Island, Texas, and Missouri, worth in excess of $100,000.

It is said that a failure to complete contracts through a temporary suspension of active business will impose upon the bankrupt estate heavy liabilities for breach of contract.

Business Improving

The electrical manufacturing companies, both large and small, continue to report a gratifying increase in orders and inquiries.

The Allis-Chalmers Company reports a lot of substantial orders and a considerable increase in the volume of inquiries, which leads to the anticipation of a heavy business in the spring. The department of mining machinery is particularly active, and much business is noted in municipal water and power plants. All the plants of the company are in operation.

The General Electric Company reports a satisfactory increase in the number of orders recently taken, and a very bright outlook for the coming spring. The main plant at Schenectady is now running at about 70 per cent. of capacity, the Lynn works are employing about 7000 workmen, while the lamp works at Harrison, N. J., are running at full capacity.

The Westinghouse Companies say that business is steadily increasing, and each week sees increase in the working force. It is anticipated that by the first of March the shops will be running at full capacity. The Westinghouse Air Brake Company went on full time with the first of the year.

The Western Electric Company is now operating at 80 per cent. of normal capacity, and expects shortly to return to normal conditions.

The St. Regis Operating Engineers' Training School

IN our last issue the mechanical plant and operating methods of the engineering department of the Hotel St. Regis were described, and attention was drawn to the notable results in the shape of improved operating efficiency and reduction of operating costs which has been attained there. It was also stated that in the opinion of those best qualified to judge, the principal factor in reaching these results was the application of the bonus system in the boiler room. This statement in its broadest sense may be made to include the whole increase in the efficiency of the operating force, of which the bonus system is but an important part. The larger credit for the success that has been attained is unquestionably the fruition of the remarkable work that has been carried on under the auspices of the organization whose official name is, "The St. Regis Hotel Engineering Department Relief and Educational Society."

This society, which, apart from its protective features is really an organized effort to improve the working force of the engineering department, may for the purposes of this article be considered as a training school for the firemen, engineers, plumbers, machinists, present and prospective, and workers of all sorts who make up the operating and maintenance staff of this department of the hotel. Its membership roll includes nearly every one of the force, and now numbers about 32.

Its objects cannot be more clearly set forth than they are in the first page of the Constitution and By-Laws, Article 2, Section 1, wherein is stated:

OBJECTS.

Article 2. *Section* 1. The objects of this Society shall be the raising of funds to provide a weekly relief income to members in good standing during illness or accident and such other relief as may be deemed advisable, and to assist in defraying burial expenses of the deceased member; also to defray the expenses incurred in carrying on the training course which constitutes the Educational Branch of this Society.

Section 2. As a further relief, members who are in good standing may apply to the Society for loans, not to exceed 10 days' pay of such member's monthly salary. Loan to be paid back in four successive and equal monthly installments plus 1 per cent. per dollar per month, on amounts due the Society.

Section 3. The object of the Educational course is to give such practical instruction and example as will further a spirit of manhood and induce the members of the department to become self-reliant, observing and manly men. Also the training such men to become safe and conscientious workmen, worthy to receive the Company's Certificate of Merit for two years' service.

Section 4. To ambitious holders of the Certificate of Merit, the training course will endeavor to supply the technical information most needed to make such workmen qualify as safe and efficient operating steam engineers, worthy to receive the Company's Operating Steam Engineers' Apprenticeship Certificate for five years' service.

It is the third and fourth sections that are of special interest to the readers of THE ELECTRICAL AGE.

The Society was organized in the summer of 1906, and owes its being to Mr. J. C. Jurgensen, chief engineer of the hotel, who is its chief instructor. This gentleman tells us that he found himself placed in charge of a plant containing every improved device for conducting the complex mechanical operations of a great modern hotel, but instinctively felt that to obtain the best performance of the system as a whole, the improvement of the men was imperative. After months of study and experiment, the organization of the society was effected.

In an address on the subject, delivered some years ago, Mr. Jurgensen says:

"The first thing to be done was to induce the whole body of men to become a conscientious group of earnest and willing workers, and to take pride in their work, be it ever so lowly. Each man must be brought to understand that the universal watchword is *progress*—progress for himself and progress for everything pertaining to the safe, efficient and economical running of the plant. To this end thorough discipline is necessary.

"The aim was to have the whole body of men in the engineering department work together as a unit for the common interest of the firm and of the men themselves. This, however, was not an easy problem. Men with the necessary qualifications could not be found, partly because they did not exist in sufficient numbers and also because experienced men want more pay than can be given for the lower positions. It had always been a matter of surprise to me that no concerted action had been taken toward establishing a suitable system of training for turning out men capable of taking charge of the ever-increasing number of large and valuable plants that are erected every year.

"I was convinced that the prime necessity for the proper running of such plants is a solid, well-knit organization of trained men, self-reliant and self-respecting, who would be able to turn in to the chief the detailed daily reports which are absolutely necessary to the successful operation of such a property."

Very wisely it was decided to begin at the beginning; that is, with the bottom grade of men.

The men for the St. Regis course are, if possible, picked from good Christian homes, such having always proved the most dependable and willing workers and students. They are those who are found to be ambitious and gritty enough to go through the different jobs in the modern plant, to study and observe as they go along, and bend their energies by a well-defined plan of procedure toward a definite end.

A young man of this type, full of energy and the desire to do the right thing, is one of the best things in the world to invest in and is well worth training, and the knowledge obtained by doing practical and thorough work and knowing why and how he is doing it will soon enormously increase his usefulness and efficiency.

The first thing after an applicant is selected is to talk with him about the general lines along which the course is conducted. A copy of the rules, which are few in number, some of which are shown on the certificates, is given him, and he is expected to make them a part of his daily conduct.

He is expected to be industrious and not to waste his own and his employer's time.

He is expected to be punctual in all his engagements.

He is expected to cultivate the habit

of attention to details and the methods of doing things.

He must understand the importance of accuracy not only to himself but to the whole organization.

The above are a sample of the general rules of conduct laid down.

At the same time it is realized that too much dependence must not be placed on rules. Too much guidance and restraint will hinder a young man in forming habits of self-reliance.

Now the motives that are held forth to induce the apprentice to submit to these conditions, and to give him the incentive to force his way through the dry details and hard work, are also made equally plain.

He is informed in the first place that all the positions in the plant are graded in a certain order from the lowest to the highest, and that every new station brings with it an increase of pay. That his record in the course is carefully kept—and kept in public—and that he is to be promoted on his merits. The powerful force of public opinion is invoked by keeping these records hung up in the engine room. He is told that vacancies as they occur are always filled by the next man in line, *if his record warrants it,* and that no outside men are brought in to deprive him of his promotion. He is told when there are not sufficient vacancies to make such promotions, reasonably certain better positions outside are found for those who are qualified to fill them, so as to make room for the promotion of others. As an additional stimulus to the foregoing advantages is added the presentation, at the completion of a certain term of service and amount of work, of a large engraved certificate of proficiency and merit, framed and ready for hanging.

Copies of these certificates are shown in Fig. 1, 2 and 3. Fig. 1 and 2 are certificates of merit, and Fig. 3 is an apprenticeship certificate, to secure which, the candidate must have earned the merit certificate and have five years of service with a good record to his credit.

Having thus laid down the broad line of the course, it is instructive to follow up in some detail the course of study which is run in along with the actual work of operating the plant.

The questions throughout the course, as may be seen from the samples submitted, are arranged in the order of importance, each one presenting a logical advance from the subject previously covered, and all arranged with a view of fitting in with and illuminating the work actually done.

The importance of small economies, the advantages of system and method in the work, the necessity of discipline and the usefulness of cultivating a habit of observation and thinking over what has been observed, and of being able to utilize it to his own advantage, are the first steps. The next thing to be taken up is the study of boilers and the boiler-room practice. Under this head 50 questions are given.

The apprentices in steam engineering are then introduced to the principles of engines and pumps, including valve setting, steam consumption and practical operating experience covered by another 50 questions.

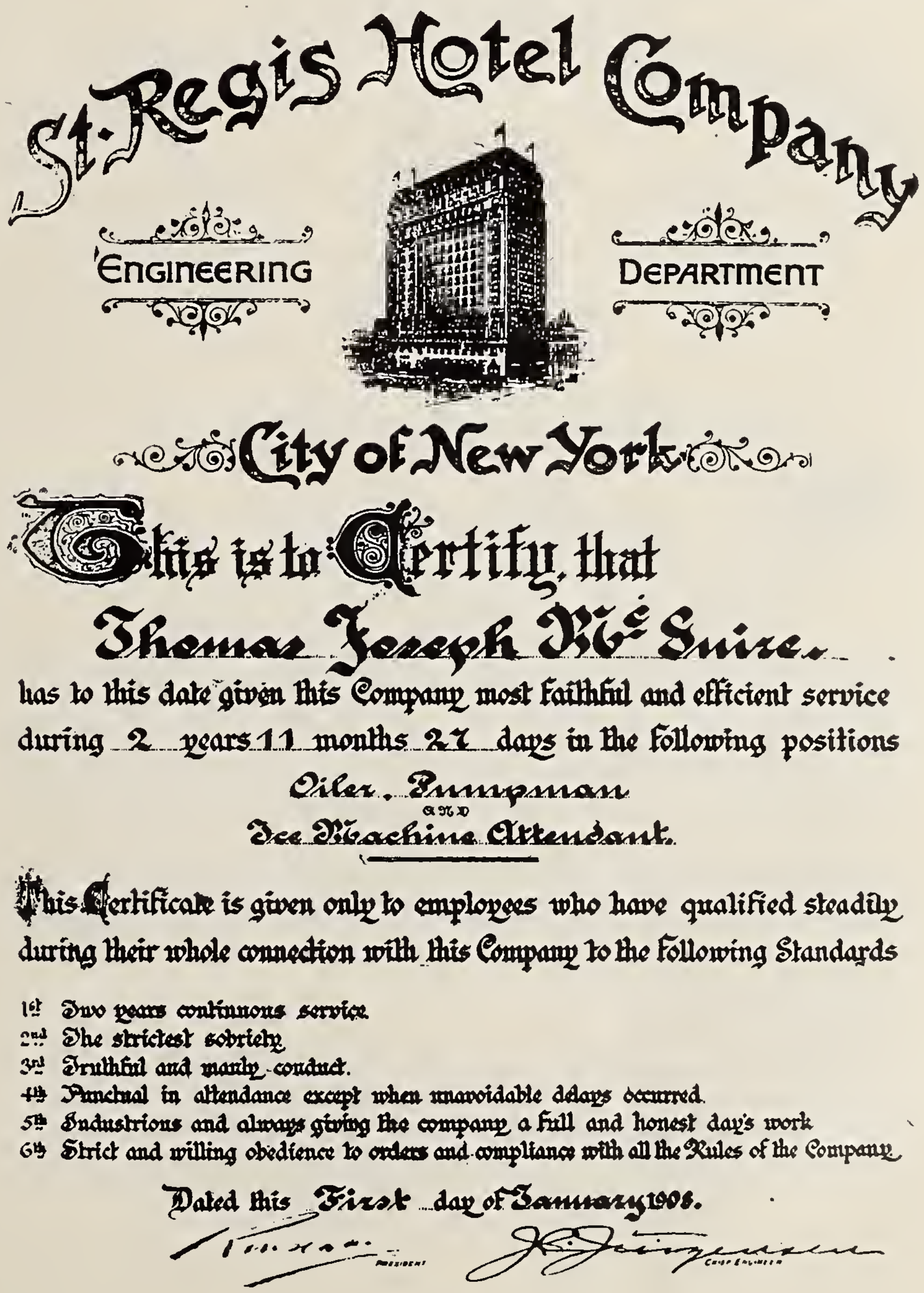
Next comes machine work, including shop methods, knowledge of metals and the handling of such metals as used in the repair of machines and found in a good plant. These are treated in 25 questions.

The entire schedule course of study for the actual steam engineer's work is as follows:

	Questions	
Boilers and boiler room practice	50	
Chemistry of combustion and evaporation	20	
Engines and pumps	30	
		— 50
Machine Work and repairs	25	
Steam fitting and plumbing	15	
Sanitation	10	
		— 25
Hydraulic elevators and their care	12	
Electric elevators and their care	8	
		— 20
Refrigeration	15	
Mechanics of absorption and compression	5	
		— 20
Heating and ventilating		20
Direct current electricity	25	
Alternating current electricity	10	
		— 35
Practical steam engineering, including sketching of work		15
Business pointers for steam engineering and engine room accounting		10
Total		270

The complete study course for this apprenticeship for operating engineers thus includes 270 questions covering the actual work as outlined, one question a week for five years. The young man generally stays five years because the law in New York calls for five years in the engine room before an applicant can be examined for an engineer's license. In addition to these 270 questions, 40 to 100 questions in arithmetic are given to the beginners before the regular study of the concrete questions can be taken up; this is done to see that the applicant can, with profit, take up the regular study.

The men are told to buy a certain suitable book on arithmetic. Wherever it is thought advisable, the name


St. Regis Hotel Company

Engineering Department

City of New York

This is to Certify, that

Thomas Joseph McGuire.

has to this date given this Company most faithful and efficient service during 2 years 11 months 27 days in the following positions

Oiler, Pumpman and Ice Machine Attendant.

This Certificate is given only to employees who have qualified steadily during their whole connection with this Company to the Following Standards

1st Two years continuous service.
2nd The strictest sobriety.
3rd Truthful and manly conduct.
4th Punctual in attendance except when unavoidable delays occurred.
5th Industrious and always giving the company a full and honest day's work
6th Strict and willing obedience to orders and compliance with all the Rules of the Company.

Dated this First day of January 1908.

President Chief Engineer

Fig. 1

of a plain textbook on mechanical sketch drawing to measure is also given to the student. It is something like the one used in Pratt's Institute, Cooper Union, or in the Correspondence School. As the man progresses, he will show the chief the results of his exercise in correct sketching for actual work he will have in hand.

The following list comprises questions chosen both from those asked in the body of the course and from those asked in the final examination for certificates. A noteworthy feature of these is their absolute practicalness. Another is the little foreword which is often placed before the question as an aid to the apprentice to attack it in the right frame of mind. It must be remembered that the men who take these courses are not always used to the mental work involved, and anything that helps them to clearly appreciate its value is doubly useful.

QUESTIONS IN STEAM AND ELECTRIC OPERATION.

EDWARD O. ISACKSON, *Assistant Instructor*

"The following questions should impress upon the mind of every man wishing to be a successful operating engineer, the necessity of absolutely correct readings. No engineer can afford to come to conclusions without careful thought and reasoning.

No. 1. On a certain date, the engineers reported, in writing, the load on Unit No. 1 to be 1600 amperes at 117 volts, and boiler pressure at 100 lb. Indicator cards taken at the same time show an initial pressure of 100 lb. and a total indicated horse power of 257.4. The friction load taken at same time showed 58.4 i.h.p. Effective indicated horse power = 257.4—58.4=199.

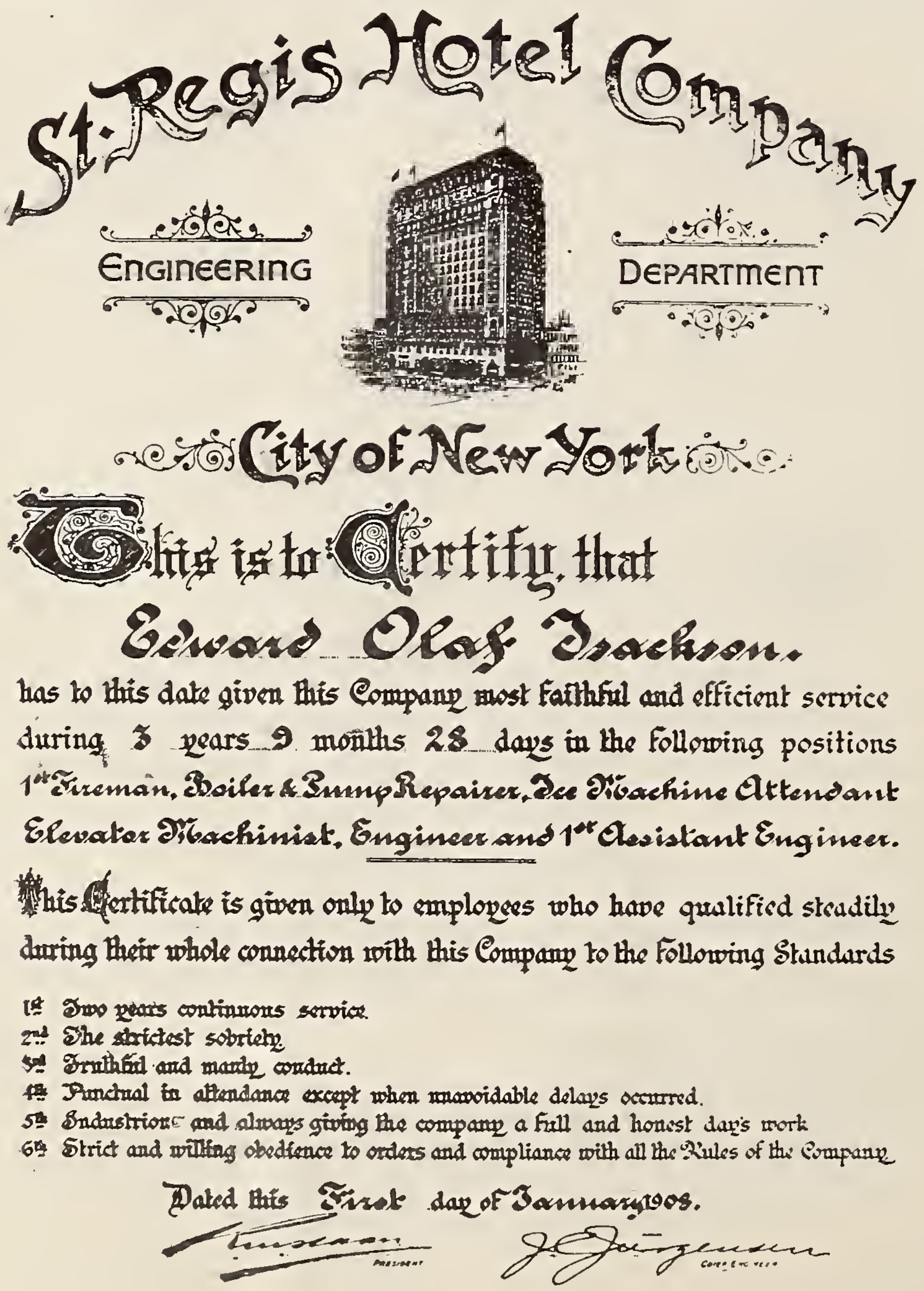
One indicated horse power = 746 watts, which equals one electric horse power. According to the above readings we produced 727 watts per total indicated horse power. This is wrong, because it is impossible to get that much under the reported conditions.

No. 1 *a*. Explain why, and how many watts per total indicated horse power is the most it can be?

No. 1 *b*. Supposing the card and the voltmeter is right, how many amperes should be read?

No. 1 *c*. Supposing everything is right except the voltmeter, how many volts should be read?

No. 1 *d*. Supposing the amperemeter and voltmeter readings are right, how many more indicated horse power should the card show?"


St. Regis Hotel Company

Engineering Department

City of New York

This is to Certify, that

Edward Olaf Isackson.

has to this date given this Company most faithful and efficient service during 3 years 9 months 28 days in the following positions 1st Fireman, Boiler & Pump Repairer, Ice Machine Attendant Elevator Machinist, Engineer and 1st Assistant Engineer.

This Certificate is given only to employees who have qualified steadily during their whole connection with this Company to the following Standards

1st Two years continuous service.

2nd The strictest sobriety.

3rd Truthful and manly conduct.

4th Punctual in attendance except when unavoidable delays occurred.

5th Industrious and always giving the company a full and honest day's work

6th Strict and willing obedience to orders and compliance with all the Rules of the Company

Dated this First day of January 1908.

President

Fig. 2

QUESTIONS IN REFRIGERATION.

LOUIS STULTZ, *Assistant Instructor*.

No. 1 *a*. Twenty-five gallons brine cooled one degree Fahr. in one minute being equal to one ton of refrigerating effect per 24 hr. What is the equivalent in tons of refrigerating effect for 24 hr., to the amount of work done per hour in our brine cooler when the brine enters the cooler at 10 degrees Fahr. and is discharged at seven degrees Fahr. and the pump discharges 28 cu. ft. per min.?

No. 1 *b*. The freezing capacity of an ice machine depends entirely on the existing conditions, such as temperature of the condensing water, the speed of the machine, etc. The dimensions of each of our two ammonia compressors on machine No. 1 are 10¾ x 20, and are double-acting, allowing 10 per cent. loss for action of suction, valves, clearance in cylinders, etc. The cubic contents of one stroke equals 1634 cu. in. With the engine making 50 rev. per min., with your gauges showing 168 lb. head pressure and 15 lb. back pressure; 3.975 cu. ft. of ammonia gas discharged per minute is one ton refrigerating effect in 24 hr. What would be the amount of work done by compressors in tons per 24 hr.?

No. 1 *c*. What size of steam engine do you need if it requires 1½ i.h.p. to produce one ton of refrigerating effect?

No. 2 *a*. What would be the amount of work done in tons of refrigerating effect in a freezing tank when 30 cans of water at 75 degrees Fahr. is frozen into ice at 16 degrees Fahr., each can weighing 150 lb.? Specific heat of ice is equal to 0.504 B.t.u.; latent heat of liquification is 142.4 B.t.u. and 284,800 B.t.u. equals one ton of refrigerating effect.

QUESTIONS ON MACHINE WORK AND REPAIRS.

FRED. SCHUMACHER, *Assistant Instructor*.

No. 1 *a*. How will you find the gears needed for cutting the threads on a ¾-in. machine bolt (U. S. Standard) if the lathe has no gear table on it.

No. 1 *b*. Give a list of numbers of threads per inch on machine bolts from ¼ in. up to 2 in. by $^1/_{16}$-in. difference.

No. 2 *a*. How will you line up an engine?

No. 2 *b*. What is the usual result to your engine if it is allowed to work with improper alignment of moving parts?

No. 3. Describe the metal, the method of making, the heat required and the tempering colors needed for first-class drills, chisels, reamers and dies.

The course also includes a number of lessons covering practical engineering. This branch is one of the longest of all, and consists in a large part of notes and sketches covering necessary connections and valves to be operated in case of shut-downs of a part of the machinery, or in case of accidents. It also includes the making of engine-run schedules.

EXAMINATION QUESTIONS.

The following is a sample of a final examination question for Apprentices' Steam Engineering Certificate:

"It is well understood by all of us that to produce results in an engine room, it is necessary to follow actual operating costs very closely, and to preserve the information gained in such a manner that it will act as a guide in all our work.

Question 1 *a*. What would you do upon entering a position in which you had been told that the monthly expense is $5,000, and that you could get the job for $150 per month and 10 per cent. of savings additional, on condition that the expenses would be reduced by 10 per cent. through your efforts. State in detail your methods for earning that extra $50.00 per month.

1 *b*. If you find in your job that a compression ice machine is used, and you also find that the return condensing water cannot be used to advantage, assuming you used 1000 cu. ft. of water per hour at 65 degrees Fahr., which cost $7.00, the steam engine driving compressors operating against a head of 150 lb. develops 75 b.h.p. each at 22 lb. steam, a boiler horse power is developed for 3.75 lb. coal at $2.50 per net ton, which is the cheapest to increase the head pressure to save water or continue the same head press to save steam.

1 *c*. In your engine room a number of small steam leaks are found either in leaky pipe and flange joints, and worn-out valve-discs, or in drop-valves carelessly left open. The total area of these holes we will assume to be equal to that of a ½-inch pipe, left open all the time. The steam pressure is 115 lb. gauge. Assuming the capacity of the boilers to be 300 h.p. and that they are worked to their full rating, what is the percentage of loss to your employer, due to these leaks? (Use Napiers' Formula for finding the weight of escaping steam.)

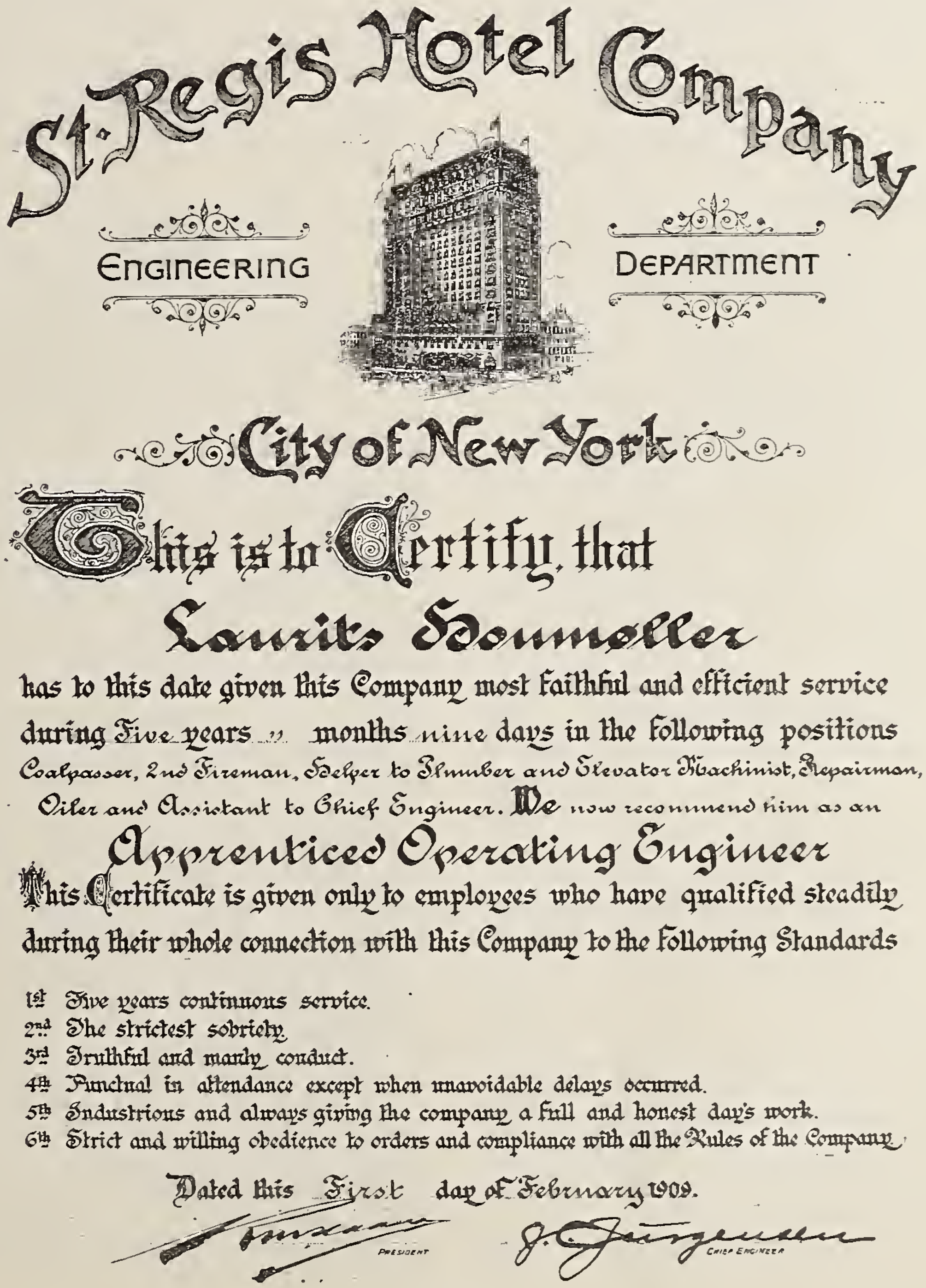
a. Assuming you used five pounds of coal per boiler horse power at $3.25 per ton, how much did you cause the company to lose by allowing those leaks to go on day and night for one year?

b. An engine and dynamo outfit the full load of which is 2500 amperes. The friction load, according to our indicator diagram, is found to be 15 per cent. at full load. If we assume the actual kilowatt-hour cost to be 1.25 per cent. at full load, how much and why do you increase the kilowatt-hour cost to the company if this outfit is allowed to run with a load of 1700 amperes?"

It is obvious that the answer to a question like this can only be made by one who has not only been "through the mill" and has learned to use the knowledge acquired by him there.

When all of the questions are numbered and printed on separate sheets and the answers are also printed in book form with the corresponding numbers, it is an easy matter for the man in charge to see how near correct the various answers are, and to ease the work for the chief instructor, who is to correct the answers; and at the same time there is a chance to exercise one of the rules mentioned on the certificate, namely, willingness to help each other. The answers to the various questions on subjects will be turned over to the man who is in actual charge of the kind of work covered by the question. If he does not know them very well himself, he is certain to be pretty careful to find out before he passes his approval or disapproval of them to the chief. In this way the whole school becomes a co-operative educational body, based on sound principles. This method also creates a desire in the older men in charge of work to show the younger men the way up, and reduces labor and time for the chief instructor, and also makes a better feeling among the men.

Where it is possible, blueprints from the manufacturers of the various machines studied are secured. This enables the men to trace off the parts



St. Regis Hotel Company

Engineering Department

City of New York

This is to Certify, that

Laurits Houmøller

has to this date given this Company most faithful and efficient service during Five years " months nine days in the following positions Coalpasser, 2nd Fireman, Helper to Plumber and Elevator Machinist, Repairman, Oiler and Assistant to Chief Engineer. We now recommend him as an

Apprenticed Operating Engineer

This Certificate is given only to employees who have qualified steadily during their whole connection with this Company to the Following Standards

1st Five years continuous service.
2nd The strictest sobriety.
3rd Truthful and manly conduct.
4th Punctual in attendance except when unavoidable delays occurred.
5th Industrious and always giving the company a full and honest day's work.
6th Strict and willing obedience to orders and compliance with all the Rules of the Company.

Dated this First day of February 1909.

President Chief Engineer

Fig. 3

involved in the discussion, and it makes a valuable addition to the course.

In order to make parts of the course clearer, some of the questions are written out in the form of short lectures. These precede each main branch before the study is taken up, and give the various, constants, tables and details needed and also refer to suitable books covering the branch, so as to enable the student to go further if he wants to. The questions for each branch are, of course, studied while the man is on that kind of work.

The questions in arithmetic, as far as possible, are on simple mechanics in order to make them serve as an introduction to the later study. It is, of course, not thought that this schedule of study is all that a steam engineer needs, but it is hoped that what he has done will instill in the more ambitious a desire to further study, and as for those with less ambition and will-power it at least helps them to make them more useful to themselves and to their employers as safe and reliable men. If this end is met, the labor expended on carrying the work on is well spent, and the results richly repay the efforts made.

REWARDS AND DEMERITS.

In a system of discipline it is very necessary to avoid anything that savors of favoritism. It must be carried on in such a way that every man has an equal chance to gain, by experience, a better position and the Certificate.

The entire scope of the disciplinary system of this course may be gathered from the following set of rules governing the award of certificates.

RULES AND METHODS GOVERNING THE AWARD OF CERTIFICATES.

Rule No. 1. Two years' continuous service.

a. Each week's service entitles to 10 points on the record. To earn a Certificate of Proficiency and Merit, 1000 points out of a total of 1040 in a period of two years' continuous service must be to the applicant's credit on the weekly record posted in the engine room.

Rule No. 2. The strictest sobriety.

a. If found under the influence of liquor while at work, immediate discharge will follow.

Rule No.. 3. Truthful and manly conduct.

a. For unwillingness to help each other, untruthful and unmanly conduct, reduction in position or discharge will follow, or a reduction of from five to 40 points from Certificate record each time.

Rule No. 4. Punctuality in attendance.

a. For each five minutes late in the coming in or five minutes early in going out, except when unavoidable delays occurred or when permission was given, deduct one point for each five minutes and ½ point for each fraction of five minutes.

Rule No. 5. To be industrious and always give the Company a full and honest day's work.

a. If found shirking and not attending to work as an honorable workman would, reduction in position or discharge will follow, or a reduction of from five to 40 points from Certificate of record each time.

Rule No. 6. Strict and willing obedience to orders and compliance with all the Rules of the Company.

a. If found to disobey orders of superiors and Rules of the Company wilfully and knowingly, reduction in position or discharge will follow, or a deduction of from five to 40 points from Certificate record each time.

Rule No. 7. Should it be found that any member of the Engineering Department neglects or misunderstands his duty by shielding actions or methods of others which in any way are detrimental to the Company, or to the welfare and reputation of the Engineering Department or its individual members, such action will be construed as a violation of Rules No. 3 and No. 6.

a. If any man has been posted on the record three times for infractions against one or all of the Rules—3, 5, 6—he has forfeited his right to receive the customary vacation with pay earned by one year's good service.

b. The fourth time a man is posted for an infraction against one or all the said Rules 3, 5, 6, he will be reduced to a lower position or he will be discharged from the service.

c. Any man discharged under one of Rules 2, 3, 5, 6, will, upon his request, receive a paper certifying to the length of time employed in the Engineering Department, and no more.

d. Any man when once discharged under one of Rules 2, 3, 5, 6, will under no circumstances receive a letter of recommendation.

e. Any man when once discharged under one of Rules 2, 3, 5, 6, will under no circumstances be reemployed. A discharge under Rules 2, 3, 5, 6, means that the man was found to be useless and a burden to the Engineering Department.

f. Charges against any man will be acted upon only when a straightforward, written statement is made and openly signed and attested to in the Daily Engine Room Record Book. This book is open to every member of the department for all questions relating to above Rules.

Rule No. 8. Any man holding our Certificate of Proficiency and Merit, and has five years' continuous service with a good record to his credit, is entitled to our Apprenticed Operating Engineers' Certificate under the following conditions:

a. Applicant for Apprenticed Operating Engineers' Certificate should, as near as possible, have worked six months at each of the following positions:

Helper to watch engineers, fireman, electrician, plumber, machinist and repair engineer. Engine oiler, ice-machine attendant and elevator repairer.

b. Length of service, ability and willingness to work in present position governs the right to be examined for promotion. If the applicant has not made use of his opportunities and is not ready to stand examination on questions relating to the desired position, the next man in the service will be examined, and with a satisfactory examination and a good record he will be promoted.

c. Applicant for Apprenticed Operating Engineers' Certificate is required to answer, in writing, to the chief and watch engineers' satisfaction, the prescribed questions.

d. Applicant must be able to read and make complete mechanical drawings. Proof of study in a correspondence or evening school will be preferred.

The training-school when it has turned out a good man is proud to stand behind him, and some of the little company who have gone out from the St. Regis engineering force have done very well. In connection with the use of the merit and bonus system wherever it could be applied, the effect of the training given has been to quicken the spirit and action of the force. The results obtained speak for themselves.

The fact that there is nothing new or original in the ideas put into practice makes it all the more remarkable that their application is not more general. Far-seeing men for a long time past have pointed out that in that way lies the only true solution of the so-called "labor problem."

The next few years will see the rapid spread of the system, and it is the hope of those who have put so much time and thought on the development of the courses described in this article that they may ultimately be able to extend their radius of action far beyond their present narrow limits and enable any good man and true in this city or elsewhere, who wishes to do so, to utilize the very real advantages to be gained by those who are willing to work and think while they work.

Public Service Commission Report

THE report of the Public Service Commission of the State of New York for the year 1908, covering both the First and Second Districts, has been made public.

In the report of the First District Commission one of the most striking facts brought out is the enormous traffic of the surface, elevated and subway roads of New York City. Last year these roads carried 1,300,000,000 passengers, which is more than half again as much as the total numbers of passengers of all the steam railroads of the United States. The total capitalization of these companies is $533,000,000 and their annual receipts from their passengers is $62,000,000. The gas and electric companies are capitalized over $386,000,000, and the former sold over 32 billions of cubic feet, which is about 20 per cent. of the entire gas production of the entire country.

The income from the sale of electricity in New York City is over $20,000,000.

The report states that it received over 3,000 complaints as to service rendered by transportation companies, and about 9,000 concerning gas and electric corporations; mostly concerning the accuracy of meters. Nearly all these complaints have been adjusted without a formal hearing, and in the few cases where one was necessary the companies have accepted the commissioner's finding and giving the relief suggested.

The problems which have arisen with gas and electric companies during the year have related principally to the instruments for measuring the service and to the conditions that the companies have sought to improve in their contracts of service. The report adds:

"The various types of electric meters in use in the city are being tested and examined to determine whether there are any that ought not to be used because of defects in principle or nature of construction.

"One of the conditions imposed by the companies when the electric inquiry was begun provided that a consumer could take electricity from no other source, even including in the prohibition his own lighting plant. This condition was gradually driving out of use the private plants in the large buildings, for the owners could not run the risk of their own plants breaking down and be without the ability to get electricity from the company. The commission has brought about an agreement upon the part of the company to give 'break-down' and 'auxiliary' service to owners of private plants."

The First District Commission then takes up the question of new legislation regarding rapid transit in the city, and makes the following recommendation:

"A constitutional amendment exempting from the 10 per cent. debt limit bonds for the construction of rapid transit lines, when, so far and so long as such rapid transit lines shall be self-supporting.

"An amendment to the Rapid Transit Act providing the operating contracts for extensions of rapid transit lines may be made to terminate at the same time as the original operating contract, the commission having the power in conjunction with the Board of Estimate and Apportionment to fix the terms, conditions and compensation and to readjust same each twenty years thereafter. Such phraseology should be used as will make it clear that extensions proceeding beyond terminals are alone intended.

"An amendment to the Rapid Transit Act which will give this commission the power in conjunction with the Board of Estimate and Apportionment to allow the construction and operation of rapid transit lines by private companies upon payment of part of the earnings to the city, or other proper terms, and with a reservation to the city to purchase at any time after a certain period, not more than twenty years and without any payment for the franchise itself.

"An amendment to the Rapid Transit Act which shall give this commission the power, in conjunction with the Board of Estimate and Apportionment, to grant franchises to existing corporations owning rapid transit lines, to construct and maintain additional tracks on the whole or part of their routes, with a reservation to the city of the privilege to purchase at any time after a certain period of not more than twenty years and without any payment for the franchise itself. Such phraseology should be used as will make it clear that extensions proceeding beyond terminals are alone intended.

"An amendment to the Rapid Transit Act making it possible for the commission, in conjunction with the Board of Estimate and Apportionment, to make operating contracts for a longer period than twenty years, or else to make operating contracts terminable at any time after a certain period of not more than twenty years, with a provision that the equipment shall be purchased at a fair price by the city at the termination of the contract.

"An amendment of the Rapid Transit Act rescinding the requirement that the operator must pay interest and a specific annual sum for sinking fund on the entire cost of a rapid transit line, and permitting the commission and the Board of Estimate and Apportionment to adapt the operating contract to the specific needs of each case.

"The commission favors permitting the cost of rapid transit lines to be assessed in whole or in part on the lands benefited, but it is not yet prepared to recommend a definite method.

"Greater freedom should be given to those who have to arrange the terms of operating contracts, and so long as the concurrent action of the Board of Estimate and Apportionment and a State board like the Public Service Commission is requisite, there is little danger that the terms will be made more lenient than the situation actually demands. These two authorities should be allowed to make the best possible terms with a private company for operating and also to undertake the municipal operation if no private operator can be secured upon reasonable terms, or if municipal operation seems preferable. The principle of acquiring interest and provision for a sinking fund would ordinarily be observed, but the city ought not to be bound to take an operator upon certain terms specified in advance, or else be compelled to adopt municipal operation."

The commission advocates the taking of bonds issued for new subways out of the city's debt limit. It is pointed out that it has been proved that subways are self-sustaining, and that therefore the constitution should be so amended as to exempt from the city's indebtedness corporate stock sold for the construction of new subways.

Concerning the attitude of the Board of Estimate toward building of new subways, the report says:

"Owing to the refusal of the board to act, subway building has been held up over seven months, and the day when the citizens of New York will be transported in decency and comfort has thereby been placed further

and further into the future. Several miles of new subway would to-day be under construction if the Board of Estimate and Apportionment had acted upon the contracts before it had authorized an expenditure of less than $3,000,000. The Public Service Commission has exercised every function bestowed upon it to secure the construction of the new routes and is in no way responsible for the fact that no work has been started during the last year upon new routes."

The commission, in referring to the report of Mr. B. T. Arnold, who was retained as a special engineer to make an investigation of the subway, that in line with the recommendations they made, it has ordered two experimental trains equipped with side doors to be put into service. It is expected that the first one of them, an eight-car train equipped with pneumatic operation to the city of the privilege to in service in the subway in February. A new system of speed-control signals is about to be tried on the express tracks.

The report of the Second District Commission is devoted mainly to questions of capitalization and accounting. There are now 85 corporations, municipalities, or individuals engaged in business that brings them under the control of the commission. Of these 313 were classed as "electrical," including 48 municipal operating plants. There were 141 street railway corporations, 48 gas and electrical and 4 natural gas and electrical corporations. The various cases of application for permission to capitalize, or to increase the capitalization that have been passed upon by the commission during the past year are taken up and discussed. One of the most interesting is that covering the question as to what extent the investing public might be justified in relying upon the authorization given by the commission as an implied certificate that the bonds or stock to be issued were worth their face value, or any other amount. This question arose upon the application of the Hudson River Electric Power Company for leave to issue $3,232,000 bonds. The commission said: "In passing upon the application for leave to issue additional capital stock, the commission will consider: Whether there is reasonable prospect of fair return upon the investment proposed to the end that securities having apparent worth, but actually little or no value may not be issued with our sanction. We think that to a reasonable extent the interests of the investing public should be considered by us in passing upon these applications. The commission should satisfy itself that, in a general way, the venture will be likely to prove commercially feasible, but it should not undertake to reach or announce a definite conclusion that the new construction or improvement actually constitutes a safe or attractive basis for investment. Commercial enterprises depend for their success upon so many conditions which cannot be foreseen or reckoned with in advance, that the duty of the commission is discharged as to applications of this character when it has satisfied itself that the contemplated purpose is a fair business proposition.

In regard to accounting, the commission calls especial attention to the fact that in the preparation of uniform systems of account it "has kept in constant touch with the corporations themselves, has invited and profited by constant comment and criticism, and has endeavored in every way to make the bookkeeping it prescribes as practical, as well as theoretically correct."

As regards service and complaints, the report states that in enforcing the provision of the Public Service Law that "every electrical corporation shall provide or keep in and upon its premises a suitable and proper apparatus to be approved, stamped and marked by the commission for the purpose of testing and proving the accuracy for electric meters furnished for use by it: "The commission found that 34 of the plants of 325 electrical corporations were not selling electric energy on a meter basis, and were therefore not required to obtain standards. Of 291 electrical corporations operating electric meters, 218 were found with no standards, or insufficiently equipped with standards. Recommendations were made to each of these companies, based upon the inspector's reports, indicating the type of instrument best adapted to the need of each company, and resulting in 167 companies equipping themselves with satisfactory standards; 51 plants operating on a limited scale filed objections to incurring the expense. Consideration was of necessity given to such objections, and where, upon investigation, the commission was of the opinion the objections were well founded, compliance with the recommendations was for the time being waived. Fourteen other companies, unable for the present to finance the purchase of standards, entered into arrangement, with the approval of the commission, for the use of instruments of companies operating in adjacent territories.

"A comparatively large number of companies having reported by June 23, 1908, the installation of the apparatus recommended by the commission, a resolution was adopted providing that each electrical corporation provided with apparatus for testing the accuracy of electric meters furnished to its consumers report to the commission the customers' meters tested each month with such apparatus beginning with August, 1908.

Increase in Telegraph Capitalization

The stockholders of the American Telephone and Telegraph Company have authorized an increase in the capital stock from $250,000,000 to $300,000,000. This increase is to provide a sufficient margin for the conversion into stock, on March 1st, of the $150,000,000 four per cent. convertible bonds which will then be outstanding. The amount of stock at present unissued is $69,413,000, the amount of stock now issued being $180,587,000.

A special meeting of the Central and South American Telegraph Company was held on February 5th, for the purpose of authorizing an increase of the capital stock from $12,000 to $14,000.

Resolutions on the Death of Frederick A. C. Perrine, Member A. I. E. E.

At a meeting of the Board of Directors of the American Institute of Electrical Engineers, held on December 11, 1908, the following resolutions on the death of Dr. Frederick A. C. Perrine was adopted:

Whereas, Frederick Auten Combs Perrine, as a graduate student at Princeton University, as electrician of the United States Electric Light Company, as manager for John A. Roebling's Sons Company, as treasurer of the Germania Electric Company, as chief engineer of the Standard Electric Company, as president of the Stanley Electric Manufacturing Company, and as professor of electrical engineering in Leland Stanford, Jr., University, was of great influence in raising the standard and extending the scope of the electrical engineering profession; and

Whereas, he, as a director and as a committeeman of the American Institute of Electrical Engineers, heartily participated in its activities, thereby extending its usefulness; it is hereby

Resolved, that the Board of Directors of this Institute considers that his death, on October 20, 1908, has deprived the Institute of a much-valued member and the electrical engineering profession of an active and resourceful worker; and, it is further

Resolved, that these resolutions be spread by the minutes of this meeting, that they be printed in the Proceedings, and that a copy of them be sent to Mrs. Perrine.

General News

It is announced by a representative of the United States Telephone Co. that a long distance telephone and telegraph service will shortly be operated in opposition to the Bell interests. A $10,000,000 holding company will be incorporated in a week, backed by Eastern and St. Louis capital.

The Mexican Light & Power Company is preparing to increase its plant from 50,000 to 124,000 horse-power, and to accomplish this, will construct 30 km. of canals and tunnels to bring water into use from rivers now untouched. Other improvements will be made, regardless of whether it is to become combined with the Mexico Tramways, Limited, or remain an independent company, furnishing light and power for the greater part of the Federal district.

The United Railways of San Francisco has completed a merger with the Stanislaus Power Company following an agreement to supply that company with power for operating the street railway lines in San Francisco. At present the power company is also selling its power to the Pacific Gas and Electric Company. It now proposes to complete a steam plant of considerable capacity in San Francisco as an auxiliary and reserve for the service.

The Great Western Power Company, the largest corporation of its kind in the West, has completed its plans for the erection of a large steam turbine plant, along the water front at Oakland.

This plant will be used as a steam reserve in connection with the hydro-electric services which up to the present is supplied by the 124,000 kw. station up in the Sierras. It will contain 5000 kw. turbines and will be arranged for oil burning. It is expected that this plant will be ready for service within eight months after the construction is begun.

The Ontario Power Co. is contemplating an addition to its generating plant which will increase the total capacity by 65,000 h.p. Another pipe line or tunnel will have to be constructed to the power house for this purpose, and the cost of the work will approximate $800,000.

The increase in the plant is made necessary because of the contract which has been executed with the Canadian Hydro-electric Commission to supply current to 14 municipalities in the provinct of Ontario. Under the terms of its charter the Ontario Power Co. may develop 180,000 h.p. When the contemplated addition is completed the plant will be able to deliver 140,000 h.p.

Recent advices from the West state that the Sanitary District Commission of Chicago has decided to increase the equipment of the drainage canal of the power plant at Lockport. At present the capacity of this powerhouse is contained in three 4000-kw., 60 cycle, 6600 volt three phase units. Two other units of the same size will shortly be put into service, and a third unit of equal capacity has been ordered from the Western Electric Co., which will complete the doubling of the capacity of the plant.

The last generator is the largest alternating current machine that the Western Electric Company has ever turned out. The delivery is for June 1st, and the contract price given as $25,748. Six General Electric transformers were also ordered for raising and lowering to and from the line voltage (44,000), the primary distribution voltage in Chicago being 12,000.

Money for New York's Trolley Cars

The report of the vice-president and general manager of the New York City Railway Company states that within two or three years $25,000,000 must be expended on the surface lines of New York City. This declaration means that another $15,000,000 should be appropriated for rehabilitation after the expenditure of about $10,000,000 of contracts already let. The receivers have borrowed on certificate of $3,500,000 and have spent, or contracted to spend, $4,000,000 more.

Westinghouse Wages Restored

Quietly and without any previous announcement of its intention, the Westinghouse Electric & Mfg. Co. has restored the wages of its 3,000 employees to the basis that prevailed before last March, when a cut was made in line with the policy of rigid economy which was then inaugurated.

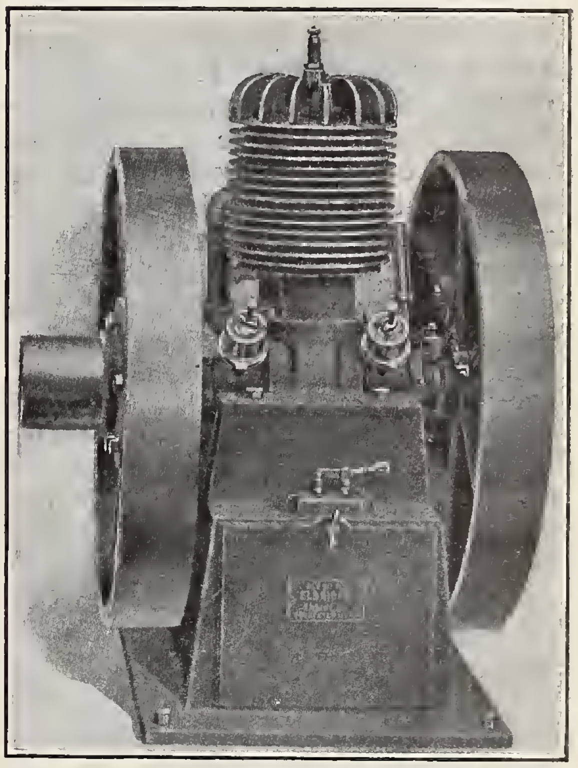
The increase in the payroll, it is said, will amount to $500,000 a year. The credit for this step is due to Mr. George Westinghouse, personally, this being his first care upon resuming the control of the property.

A Neat Lighting Outfit

An inexpensive, though high-class and practically fool-proof, electric-lighting plant to meet the demand created by the rapidly increasing number of suburban residences, is about to be placed on the market by the Elbridge Engine Company, of Rochester, N. Y.

With the intention of meeting a particular demand, the company plans to make these plants regularly in only two sizes—a 20-lamp and a 50-lamp size (16-c-p. lamps), the smaller of which is expected to be large enough to illuminate the general run of suburban homes, and which can be installed, complete, for less than $200.

Entirely self-contained, the engine, base, dynamo and rheostat weigh less than 600 lb., while the outfit occupies a floor-space of only 2 ft. in width, by less than 6 ft. in length. A specially designed Westinghouse dynamo, 1½ kw., is connected by belt with an Elbridge "Gem" 2-4 h.p., 2-cycle, air-cooled engine, described by the makers as the most simple and at the same time the most powerful for its size on the market. It is complete, as shown in the illustration; oil and gasoline, batteries and coil occupying separate compartments in the base. Absolute cleanliness is secured by the elimination of all outside oilers. So great is the radiating surface of the cylinders that no fan, beyond the specially designed spokes of the fly-wheels, is required to keep it cool. The manufacturers claim that its



efficiency is affected neither by heat nor cold, and that it starts as readily and runs as well with the thermometer at zero as at 100 degrees Fahr. in the shade.

Two pulleys are provided, one on each side. That operating the dynamo has a friction clutch, so that the engine may be started without load. On the opposite fly-wheel is a solid pulley. This combination allows the owner to use the engine for such purposes as pumping water, running sewing or washing-machines, cream separators, etc., when its power is not required for lighting. Full description of this attractive little plant may be had on application to the Elbridge Engine Company, 19 Culver Road, Rochester, N. Y.

Questions and Answers

Question.— *I have a tungsten lamp which has blackened up considerably, much as the old carbon filament lamps used to. What is the cause of it?*

Answer.—An occasional lamp in a batch of tungsten metallic filament lamps will blacken as you describe. Manufacturers are unable to satisfactorily explain this, but think it due to faulty or careless work on the part of some operator during the course of manufacture. If you will call the attention of your lamp agent to this lamp, he will probably replace it with a new one, free of charge.

Question.—*Is it good practice to parallel the low-tension side of transformers in a lighting district where there are several close together?*

Answer.—It is entirely advisable to parallel the low-tension side of the transformers, provided they have such characteristics as permit satisfactory operation in parallel. The advantages are in working the transformers at a better load and in utilizing the copper in the secondary distribution system to the best advantage. It is advisable, however, that each transformer be properly fused, so as to cut itself out in case of being damaged. A fuse of lesser capacity should be placed at some point in the primary, so as to protect the entire group against ordinary fuse-blowing troubles, and also permitting quick replacement.

Question.—*If one transformer in a bank of three delta-connected single-phase transformers is cut out, what is the affect on the three-phase apparatus fed from the bank? How is the load on them calculated?*

Answer.—The load on the bank will remain unchanged, as there is no change in the conditions of the circuit where the load is balanced. It will be divided between two transformers instead of three, as before, and would be calculated in the same way as before, *i. e.,* by multiplying the measured ampere by the measured volts and the product multiplied by $\sqrt{3}$, assuming that the power factor of the load is unity. In case the power factor is not unity, the product of the above quantities must be corrected accordingly.

Question.—*What is meant by the "saturation factor" of a machine, such as a dynamo or motor?*

Answer.—As defined by the Standardization Rules of the A. I. E. E., the saturation factor is the ratio of a small percentage increase in the excitation of the magnetic field of the machine to the corresponding percentage increase in the volts thereby produced. The saturation factor is, therefore, a criterion of the degree of saturation attained in the magnetic circuit of the machine at any degree of excitation selected. Unless otherwise specified, however, the saturation factor of a machine refers to the excitation existing at normal rated speed and voltage. It is determined from measurements of saturation made on open circuit at rated speed. The "saturation factor" should not be confounded with the "percentage of saturation to which it has the relation

$$p = 1 - 1/f$$

where f is the saturation factor and p the percentage of saturation ratio."

Question.—*How does a Mercury Arc Rectifier work and is the current obtained therefrom a direct current?*

Answer.—A Mercury Arc Rectifier has three essential parts: (1) The tube; (2) Reactance; (3) Panel, switches, etc. The tube is an exhausted glass vessel containing a small amount of mercury. It has four terminals, the two on the opposite sides being connected directly across the alternating-current supply are known as anodes. The middle or bottom terminal forms the positive terminal of the direct-current circuit, and is known as cathode. There is also a small auxiliary-starting anode for the purpose of striking the arc. The reactance is simply an inductive resistance connected in parallel with the anodes above mentioned directly across the alternating current line, and a tap from its middle point forms the negative terminal of the direct-current circuit. The panel and the switches are used to control the operation and make the various connections. The action of the rectifier is, briefly, as follows: The alternating-current supply is made alive to the reactance and the anodes. As there is no conducting element across the two anodes, no current will flow.

The tube is shaken, a metallic connection is made from the starting anode to the cathode, which in turn starts an arc, and this arc gives off the vapor. Mercury vapor has the very peculiar property of conducting current from a positive wave, but forms an insulator to a negative impulse. As each of the anodes become alternately positive and negative each cycle, the current will follow the vapor from that anode, which at that particular instant is positive to the cathode. At the same instant the remaining anode is negative and this half of the wave is being stored, as it were, in the reactance to be given off on the next reversal, or in other words, the reactance acts as an autoconverter, which steps down the voltage in approximately a two-to-one ratio. Thus, we get a unidirectional current, the current being from the positive cathode through the receptive device, such as Battery, Motor, etc., back to the negative terminal of the circuit or the middle point of the reactance. The current thus derived is a rectified current and is similar in wave form to the current derived from a direct-current arc machine, and is entirely satisfactory for all classes of work requiring a direct current.

Question.—*We have a five horse power, two-phase, 220-volt induction motor with a starting compensator that operates in a very peculiar manner, and we would like to know if you can tell us what is the trouble? The line voltage is O. K. We throw in the compensator and the motor starts promptly, comes up to speed and continues to operate at the proper speed after the switch is thrown to the running position. When, however, we throw on a moderate load the motor begins to slow down, and if the load is not lessened a fuse blows.*

Answer.—If you will remove the cover from the compensator and look at the switch contacts, you will undoubtedly find an open circuit on the running side. The motor starts two-phase, and upon being thrown over to the running position it runs on single-phase current, which it will do as long as there is no load. Naturally, when you throw on a load the speed drops, and the one-phase being overloaded promptly blows a fuse.

Question.—*Is it possible to run a direct-connected engine-driven alternator in parallel with synchronous motor-driven alternator with good results?*

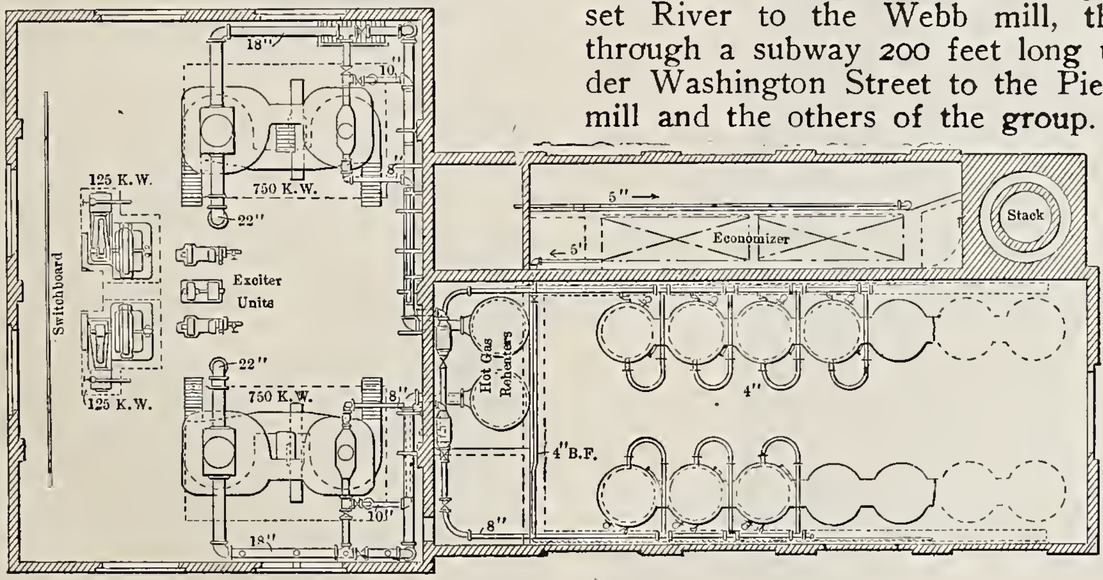
Answer.—There is no difficulty, whatever, in running an engine-driven alternator in parallel with a synchronous motor set, provided you observe the usual precautions in synchronizing two alternators. Inasmuch, however, as it will be impossible to vary the speed of the motor generator set, the speed of the engine will have to be varied by the governor or throttle. Once they are in parallel the operation will be entirely satisfactory. The engine, however, will take a constant load depending upon the position of the throttle, and the motor generator set will take the variations in load.

Vice-Consul H. G. Baugh, of Canton, China, furnishes the names of importers of dynamos and motors, machine tools, electrical goods, and iron and steel products, which are filed for reference at the Bureau of Manufacturers.

Engines and Generators in the Manufacture of Chocolate

The various plants of Walter Baker & Company, Ltd., at Dorchester, Mass., devoted to the manufacture of chocolate and cocoa products, are now operated electrically from a central power plant which is especially well suited to show the economies of electrical distribution. A considerable group of buildings is served from the central plant, no one of which requires enough power to make it an easy matter to select a very economica individual power-plant equipment, yet, as a whole, requiring an output large enough to insure a considerable saving in the cost of power.

The mills comprising the Baker group are all large and have until lately been operated by separate steam plants and line shafting. The change over from several individual plants using line shafts to a central power plant transmitting electrical power was decided upon three years ago and has only quite recently been fully carried into effect. The small boiler and engine rooms of the old systems naturally require more attention than the big units. The use of the electric motor has made the consolidation possible, with all its advantages of cheaper power, and the saving of friction lost in long line shafts.



PLAN OF POWER-HOUSE

The new power station of Walter Baker Company stands separated from the mills to which it supplies power, in order that any of these units may be expanded without interference. From the Neponset River an ample supply of circulating water is available. The engine room is sixty by eighty feet, while the boiler room has practically the same floor area. The material used in construction is brick on concrete foundations.

The plant was designed for an ultimate capacity of 2800-horse-power in boilers and 1750 k. w. in generating apparatus. The principle units in the station are two large Allis-Chalmers vertical cross-compound engines, each 22" and 48"x48" stroke, operated at 120 revolutions per minute and direct connected to 750 k. w. Allis-Chalmers' generators. There are in addition two smaller units consisting of 18"x26" simple horizontal engines, each direct connected to Allis-Chalmers 125 k. w. alternators, operating at a speed of 177 revolutions per minute.

The electrical generators deliver three-phase alterating current at 600 volts, which is transmitted directly to the mills for lighting and power use. The circuits to different mills have recording meters for measuring power consumed by each separate department. Induction motors are used all through the several units now, there being over 100 machines, ranging from 1 to 75-horse-power, installed. These motors are arranged for either individual or group drive.

The arrangement for lighting the group of works buildings is quite elaborate. It is done on a two-wire system at 110 volts, the voltage being reduced from the power feeders by transformers at each mill. These feeders are carried to the various mills through a steel bridge from the power plant, first to the Baker mill, then over a bridge across the Neponset River to the Webb mill, then through a subway 200 feet long under Washington Street to the Pierce mill and the others of the group.

Niagara Power Treaty

A treaty for the settlement of the points of difference between the United States and Canada, relating to the Niagara Falls and the Great Lakes, was recently signed by Secretary Root, and the British ambassador. By the terms of this treaty, it is provided that the level of Lake Erie must be maintained. At Niagara, the United States has a right to use 20,000 cu. ft. per second for power purposes; Canada may use 36,000. This apparently fixes for some time the ultimate limit of power developments there. The treaty also provides for a commission to dispose of future problems that may arise in administering its provisions. The level of Lake Michigan is not specifically mentioned, so that the status of the Chicago drainage canal is not affected.

Canadian-Pacific Electrification

It is reported that the Canadian-Pacific Railway has decided to electrify its system through the Western Mountains. About a year ago a commission was put in the field to investigate the available water supply between the Rockies and the Selkirks. The report states that there are enough of water falls lying along the main line "to develop sufficient energy to run all the railways in the world." It is stated that many water-power sites have been purchased and options obtained on others.

Advertising with Flaming Arc Lamps

The first flame arc lamps used in this country were of foreign manufacture. It was, however, only a comparatively short time after their introduction that the American manufacturers awoke to the realization that the lamp was destined to play an important part in decorative lighting. The result was that at the present time there are several American-made lamps on the market, all of which are widely advertised.

Although in foreign countries the flame arc lamp has been widely adopted for street illumination, its use in this country is confined principally to the illumination of store fronts and amusement places, such as theatres, parks, etc. While its use in connection with mercantile establishments is principally to attract attention, it can, at the same time, be used to advantage for the illumination of the store windows, thus serving a double purpose. For this service the lamps are suspended from suitable supports just above the top of the window.

To the brilliant light emitted by the flame arc lamp when in operation, is due its advertising or attention-attracting quality. The entire globe seems filled with a luminous gas, and, although the light has the property of penetrating the thickest fogs or smoke, it is soft and not blinding to the eye like the enclosed arc. Carbons giving a yellow or orange-colored light are generally used, but carbons may be obtained that will give a light of a red or white color.

The accompanying illustration shows the front of a department store in Schenectady, N. Y., lighted with four-flame arc lamps of a type manufactured by the General Electric

Company. This illustration was reproduced from a photograph taken at night solely by the light of the lamps, and, although it fails to show the true beauty of the illumination, gives an idea of how the store appears at night. This is only one of many similar installations in this city, and it is interesting to note that the merchants have clubbed together and made arrangements to have the entire business section lighted with G-I Flame Arc Lamps. The lamps will be spaced at equal intervals along both sides of the street and at the same height from the sidewalk.

In this type of lamp several good points of construction may be noted.

All clock mechanism is eliminated, thus producing a lamp of simplicity and one free from the troubles common to more complicated lamps. Instead of the carbons being placed one above the other, as in the ordinary arc lamps, they are placed at such an angle that they form a V, the arc forming at the lower end. All of the light is directed downward and the absence of any obstruction below the arc prevents shadows being formed. The carbons are fed in such a manner that flickering is prevented and it is impossible for one of them to slide past the other and cause the lamp to go out. Every part of the mechanism is accessible when the casing is lowered. As regards efficiency, this type of lamp takes less power per unit of illumination than any other illuminant in commercial use.

In designing the lamp special attention has been paid to its external appearance. The shell is made of copper or steel and finished in antique copper or bright japan. The globe is not held by the wire network, but is securely fastened by a flange and ring at the top, the net being retained to prevent the glass from falling, should the globe be broken. The entire length of the lamp is only 31 in. These lamps operate satisfactorily either in series or in multiple on alternating or direct-current circuits, and will burn any approved make of flame carbons now on the market.

The Chicago Electrical Show

The fourth annual Electrical Show, held at the Coliseum, under the auspices of the Electrical Trades Exposition Company, was well attended up to the closing night, January 30. The Coliseum was most handsomely decorated. A dark-blue cloth studded with miniature incandescent lamps, imitating the appearance of the night sky, formed the roof. The booths were painted white, and as the most of a 1000-kw. load was used in the production of light, mostly by the new tungsten lamp, the effect was brilliant.

Special features from time to time during the two weeks of the show attracted many out-of-town bodies. On Monday, January 18, souvenirs in the shape of Billikin pins were distributed, and on Tuesday, January 19, a special effort was made to render the remarkable United States Navy exhibit of particular interest to army and navy men. On Wednesday, January 20, the Chicago Electric Club listened to an address by Lieutenant-Commander Witherspoon on the use of electricity on the modern battleship, and on Thursday morning a large delegation from Louisville, Ky., attended the exhibit in a body. On Friday, January 22, the members of the Northwestern Electrical Association were in attendance, and during the day and in the evening there were many gatherings in connection with the meeting of the Chicago Section of the Illuminating Engineering Society. Saturday, January 23, was designated as Students' Day, and Sunday was a day of rest, not a single exhibitor being in attendance at the Coliseum.

On Monday, January 25, souvenirs were distributed, and Tuesday was made especially attractive for the telephone men. On Wednesday evening there was a grand rejuvenation of the Sons of Jove. On Thursday evening the Thomson-Houston reunion was held, the addresses being preceded by an informal dinner early in the evening.

Popular concerts were rendered by John C. Weber and his famous band, and Miss Blanche B. Mehaffey was the soloist this year, entertaining the visitors afternoon and evening with her rendition of classical and popular songs.

Tungsten lamps and vacuum-cleaning outfits were the two specialties that showed the greatest increase over last year's show. Flaming arc lamps were also much in evidence.

A list of the principal exhibitors was given in the January issue of The Electrical Age, and they were all there and many more. It is impossible to mention even in passing the innumerable electrical details that were on exhibit. Their presence, however, helped to round out the show and make it an instructive and successful exhibition. They also helped to impress on the visitor the rapid increase of the applications of electricity to the home uses of the people.

A Bit to Bore Square Holes

The old proverb about the round plug in the square hole will have to be revised when the triangular bit for boring square holes is put on the market by the Radical Angular Drill Company, of New York.

The device, which is a German invention, will bore a square hole with the same facility and nearly the same speed that an ordinary drill will bore round holes in the same material.

The present methods of making square holes, outside of punching and casting, such as by boring round holes and then working them up to the shape desired, are expensive and slow. The only appliance needed for the use of this tool on such machines as lathes, drill-presses and milling machines is a special chuck. In the chuck lies the essence of the invention, which consists of a scheme for forcing the motion with the drill in such directions as to strike out a square hole. The illustrations give an idea of how this is accomplished.

This chuck contains three parts that move independently of one another. First, a part which screws onto the spindle of the drill and revolves with the latter; second, a stationary part which rides upon the part first mentioned; and third, a holder into which the shank of the drill is screwed.

This holder is caused to rotate with the part first mentioned, but is at liberty to move sidewise a certain distance in any direction. Its exact motion is determined by a guide in the second part of the chuck, which surrounds the shank of the drill. The shank of the drill is three-cornered, but not exactly triangular, that is, the three sides are convex, being formed by arcs of circles struck from centers at the opposite corners. The three-cornered shank just fits into the square guide, and as the shank turns about in the guide, which is held stationary, the three corners of the shank in turn enter into each of the four corners of the guide. At the same time, the three corners of the cutting head strike out the sides of the work. It should here be explained that the cutting edges are on the end of the tool, not on the side, being in this respect similar to the ordinary twist or flat drill. For drilling holes of different sizes only one chuck is required, the guide in the chuck being so constructed that the opening can be enlarged and diminished by turning the key.

The motion of the three-cornered shank of the tool within the square plate can be better understood when it is remembered that the radius used to strike out the three sides of the shank is just equal to one of the sides of the square formed by the guide. Therefore, if one side of the shank is rolling or sliding on one side of the guide, the opposite corner of the shank will be moving in a straight line corresponding to the opposite side of the guide, *i. e.*, during a certain part of the revolution the corners of the tool travel in straight lines, along the outside of the square.

If it is desired to bore out a complete square with sharp corners, a special tool is used. The tools for both the round-cornered and sharp-cornered squares can be ground by means of a special attachment to the ordinary drill-grinding machine.

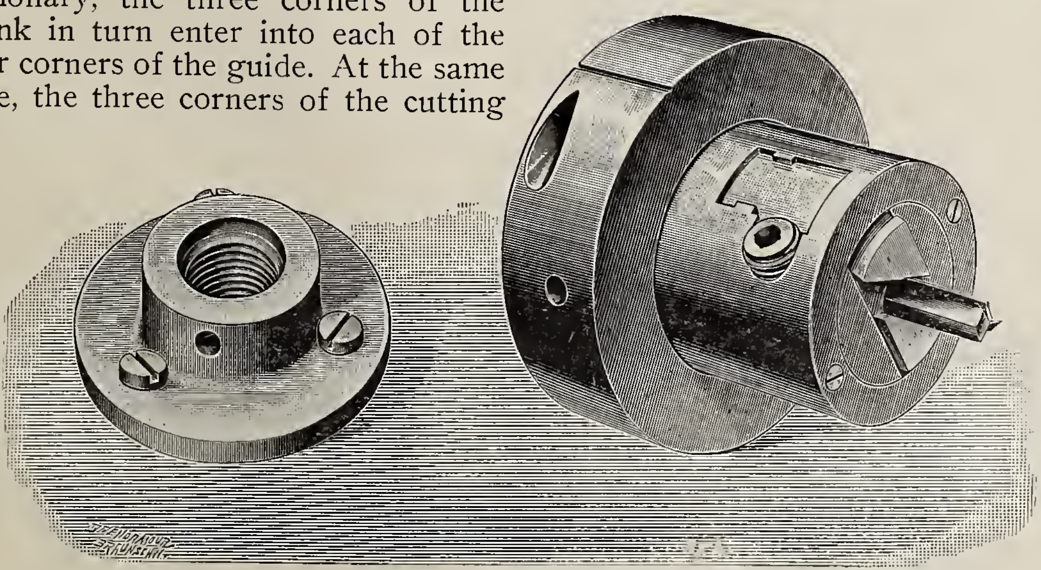


Fig. 1

New Feed Water Regulator

A growing interest in devices for regulating automatically the feed of water to steam boilers, so that the inflow will always be equal to the rate of evaporation, should insure a wide and careful reading of the handsome treatise on this subject just issued by the American Boiler Economy Co., North American Bldg., Philadelphia, Pa. This book describes the Copes Boiler Feed Regulator and takes up in turn the several advantages to be gained by automatic regulation, such as protection to the boiler, protection to the engine or turbine, saving of cylinder oil, lessened friction and wear in the engine, higher efficiency of the super-heaters, higher efficiency of engines and turbines, and greater economy from exhaust steam feed-

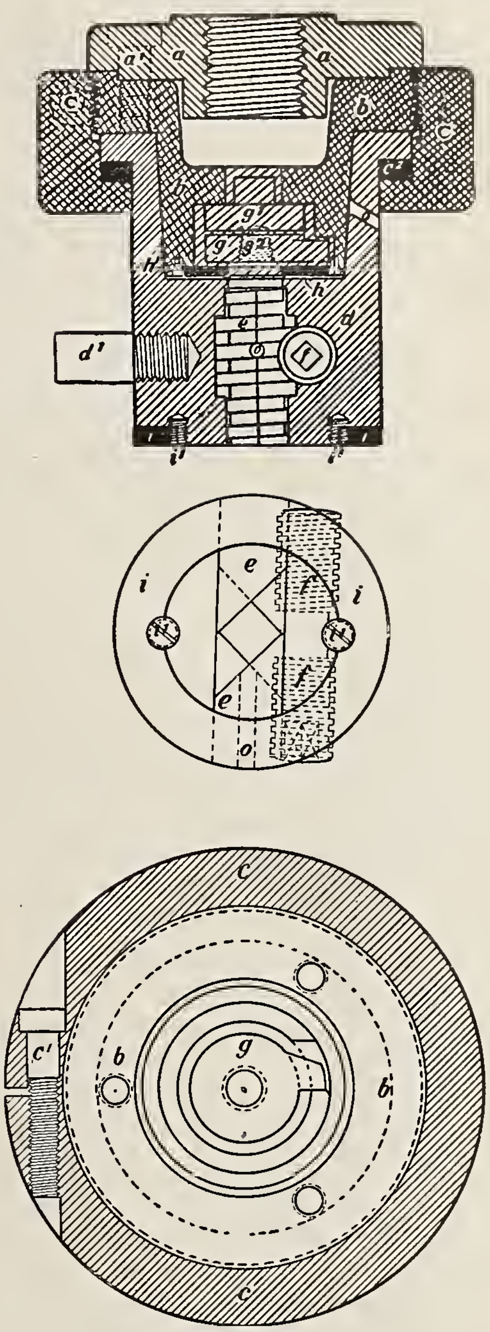


Fig. 2

water heaters and fuel economizers. The engineering considerations in regard to each of these points are brought out fully, bullseye charts from recording thermometers being shown, for instance, to demonstrate the fuel saving realized by holding the feed always equal to the evaporation. In addition there are numerous illustrations showing installations of Copes Regulators, also the manner of operation and construction of the regulator and of the Copes Pump Governor employed to insure a constant excess of pressure in the feed line. This appliance is especially valuable in large plants where the water level must be maintained in a great number of boilers and should be of much interest to consulting, designing and managing engineers.

The January Technical Press

Leading Articles of General Technical Interest

Commercial

"Electric Industry in Germany," Waldemar Koch.

Gives a brief history of the rise of the great German electrical manufacturing companies, and closes with some figures showing that the Germans both absolutely and relatively are ahead of this country in activity. The production per employee in the United States, however, is much larger.—*Elec. Journ.*

Detail Apparatus

"Automatic Control of Direct-Current Motors," D. E. Carpenter.

Describes the latest forms of the detail apparatus used for the control, and protection of direct-current motors.—*Elec. Journ.*

"Meter and Relay Connections," Harold W. Brown.

Continues the series, and gives diagrams showing the various forms of connections for station voltmeters, ammeters and single and poly-phase wattmeters.—*Elec. Journ.*

Electric Railways

"High-Tension Current Collection," Otis Allen Kenyon.

An analysis of the results of the experimental work carried out by the Swedish Electric Railway Test Commission. These results point to a type of collector which would consist of two parts, namely, a main part to take up the variations in the height of the wire, and an auxiliary part to meet the conditions imposed by vibrations. The main part would be large enough to take care of the current collected, and would be spring-supported so as to give constant pressure irrespective of the positions of the shoe. The auxiliary part, which should trail, would be light and designed to have a natural period of vibration such as to enable it to correspond with those of the car.—*Elec. Ry. Journ.*

Generators and Motors

"The Single-phase Commutating Motor," B. G. Lamme.

From a paper presented at a meeting of the Philadelphia branch of the American Institute of Electrical Engineers. The finer points in the design of this type of motor are discussed. The relation of brush-resistance and the neutralizing winding to proper operation are pointed out, and the effect of the power factor is analyzed. The paper closes with the statement that within the past five years between 200,000 and 250,000 h.p. of single-phase traction motors have been sold here and abroad, and prophesies a great future for them in heavy railway work.—*Elec. Journ.*

Management

"Rate Regulation of Electric Power," S. S. Wyer, M. E.

An article on the principles of electric power rate regulation, particularly as seen on the legal and economic sides. A number of court rulings are given and also two charts. A curve showing the effect on the cost of the customer's use of electric power is also given.—*Cass. Mag.*

"The Economical Development of Toll Territory," Frank F. Fowle.

An exhaustive study of the best methods of handling a telephone territory—runs through several numbers. —*Elec. Rev.*

"Problem of Reducing Accident Damages," Frederick W. Johnston.

A series of articles setting forth the latest attempts to solve one of the most vexatious problems that confront the management of large urban traction systems.—*Elec. Ry. Journ.*

Miscellaneous

"American Hydro-electric Construction Abroad," H. Lester Hamilton.

An illustrated account of the work of American electrical engineers in foreign lands. Among the plants discussed are those of the Mexican Light & Power Company at Necaxa, the Sao Paulo Tramway, Light & Power Co., Sao Paulo, Brazil, and plants in Japan and India.—*Cass. Mag.*

"Foreign Transportation Problems," E. F. Colyer.

An illustrated description of some of the difficulties encountered in handling heavy electric machinery in out of the way corners of the world, and the ingenious devices by which they are overcome.—*Gen. Elec. Rev.*

Power Plants

"A Recent Swedish Hydro-Electric Plant," P. Frenel.

An illustrated account of a 3000 h.p. water-power plant at Hemsjo, in southern Sweden.—*Elec. Wld.*

"Dalmatian Carbide Works Using 30,000-Volt Generators."

An illustrated article describing the new addition to the power plant of the Dalmatian Hydraulic Power Company's at Manojlovac, on the Kerka River, where Ganz & Co. have installed four 6500-kw., 420 rev. per min., 30,000-volt, 42-cycle, three-phase generators, which have been operating without trouble of any sort for nearly two years. This is by far the highest voltage for which generators have yet been wound.—*Elec. Rev.*

"Hampton Power Plant of the D. L. & W. R. R.," Warren O. Rodgers.

An illustrated description of an up-to-date 2500-kw. turbo-generator plant, which is the largest in the anthracite coal region.—*Power and Eng.*

"New Power Plant of the Carnegie Institute," Thomas Wilson.

A very complete illustrated description of a large isolated plant of excellent design and unsurpassed finish. The plant is used for furnishing light, heat and power to the huge Carnegie Institute group of buildings at Pittsburg.—*Power and Eng.*

Prime Movers

"The Development of the Small Steam Turbine," Chas. A. Howard.

This is the sequel of an article in the preceding issue in which Mr. Howard described the various features of design and construction of the principal types of small steam turbines, in use in the United States. In this, the concluding article, the various forms of service applications for which the small turbine is best suited are pointed out. The services mentioned include small electric generators, exciters for large generators, centrifugal pumps of all sorts, centrifugal fans and blowers and high-speed machinery of any type. Attention is called to the first cost economy and maintenance costs of the small turbine as compared with those of reciprocating units of like capacity.—*Eng. Mag.*

Theory

"Alternating Currents and Their Application," Edson R. Wolcott.

A serial continuing through the month, gives an illustrated description of induction and repulsion motors and transformers.—*Elec. Rev.*

"Influence of Frequency on the Equivalent Circuits of Alternating Current Transmission Lines," A. E. Kennelly.

A study of the various methods of determining the effects of the frequency on the values of the several characteristics of an alternating-current circuit.—*Elec. Wld.*

"The Energy of Steam," J. W. Kirkland.

The second of a series of practical articles on the energy of steam, and the various devices for its conversion into useful work.—*Gen. Elec. Rev.*

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NOTICE TO ADVERTISERS

Insertion of new advertisements or changes of copy cannot be guaranteed for the following issue if received later than the 15th of each month.

CONTENTS

EDITORIAL

LEADING ARTICLES

Preliminary Reports on Electrical Industries

The preliminary reports of the United States Census Bureau for 1907 on "Central Stations" and "Electric Railroads" contained some interesting statistics of the condition of these branches of electrical industry at the end of 1907, as compared with 1902.

An analysis of these reports shows clearly the prevailing tendency of the last five years. In the central station reports, which for purposes of comparison are tabulated with the report of 1902, is indicated the steady and solid growth during this period. It shows 4714 establishments as compared with 3620 at the end of 1902. This is an increase of 30%. 1252 of these plants are municipal, the increase of this class of plants being 53.6%. The tendency to consolidate plants is noticeable in this branch, but somewhat less so than in the traction industry.

The effect of the campaign for a power load shows in the statement that while the companies' income from lighting increased 76.6%, the increase of income from other electrical sources was 217.2%; in other words in 1902, the proportion of income from power service to the total income from electrical services was 16.7%; in 1907 it was 25.4%. The horse-power of motors connected with the circuits of the companies increased from 438,005 in 1902 to 1,649,026 in 1907, being an increase of 276.5%.

Another notable feature is the increase in water-power plant capacity, which was over 207% in the five years, while the capacity of steam and gas-driven plants increased but 92.8%.

The rapid increase in the growth of electrical traction is illustrated in the report on electric railroads. It shows 1236 companies as compared with 987 at the end of 1902, an increase of 25%. The total number of cars was 83,641, of which 70,016 were passenger cars. The number of passenger cars increased by 16%. The number of freight cars more than doubled. The total mileage of main lines was 25,547 as compared with 16,651 in 1902; an increase of 53.4%.

The passengers carried in 1907 numbered 9,533,080,766, which is an increase of 63% for the five years.

The fact that the total output of stations now amounting to about four and three-quarter billion kw-hr. has increased by 110%, while the number of power-plants only by 22 or 27%, shows that these companies also are finding other uses for their power than merely the hauling of passengers and really is a measure of the absorption of the light and power companies by the traction interests.

The total income from all plants is more than double for an increase of less than 100% in plant costs. This is, of course, due partly to the economies resulting from the replacement of several small plants by one large one and to the improved load factors obtained, as well as to the late improvements in power plant machinery and in the management of electric properties.

It is also to be noted that while steam and gas-driven plants furnishing power for railroad uses have increased 83.4%, water-power plant capacity has increased 86.5%, which fact, taken in connection with the above-mentioned increase of over 200% in water-power plants for central station service, emphasizes the importance of the question of the control of this source of energy which was recently raised by President Roosevelt and was touched on in the last issue of the ELECTRICAL AGE.

The total gross income of the traction companies was $429,744,254, an increase of 71.6%, but the net income of $40,340,286 represents an increment of but 31.8%, which tends to confirm the impression that electric railroad service cannot be materially cheapened under present conditions.

The income and expense statistics for the central stations are not complete enough to make a close comparison. Probably with the final report a complete analysis will be rendered.

From the data submitted the question as to the relative rapidity of growth of the two branches is not easily determined, but from other evidence it appears that the traction interests are larger, and that they frequently obtain their growth by absorbing the lighting industry of their territory.

Edwin Reynolds

On another page of the issue is given a sketch of the career of Edwin Reynolds, in whose death the engineering world loses one of its masters. Although connected directly with the development of the steam engine, so allied is this with the changes that have taken place in the generator, that the electric industry, scarcely less than the steam engine builder's, is indebted to his genius. For this reason it is not unfitting that the debt be acknowledged in these pages.

Perhaps the most conspicuous of the services rendered to the electrical world by Mr. Reynolds was the design of the great 12,000 horse-power engine for the power plants of the traction companies of New York.

The brilliancy and value of this feat are in no wise lessened by the fact that with the advent of the high-speed turbo generator, it is unlikely that any such machines will ever be built again. They will run for many years to come as a not unworthy monument of what the men of the early days of the electrical age could produce.

Western Representation in the A. I. E. E. Management

For some time there has been a feeling in certain sections of the country that the western membership has not been represented on the governing body of the American Institute of Electrical Engineers to an extent proportional to its numerical importance.

The custom has grown up that the highest honors of the Institute are as a rule to be the reward of faithful service on its board of managers. While, for very good reasons, this has not always been the case, the exceptions have been just about frequent enough to prove the rule. This being the case, the constitution of the board of managers becomes of special interest.

A glance at the list of 12 managers shows that none comes from the Pacific Coast, none from the trans-Mississippi country and only one from the States lying west of the Pittsburgh meridian. The geographical distribution of membership in the West is somewhat as follows:

WESTERN MEMBERS.
TOTAL IN UNITED STATES, 5,224.

GROUP I		GROUP II		GROUP III	
West of Rocky Mountains		Between the Rockies and the River		West of Pittsburgh	
California	265	Montana	28	Wisconsin	109
Arizona	7	North Dakota	5	Michigan	51
Idaho	11	South Dakota	7	Ohio	254
Nevada	10	Minnesota	62	Indiana	84
Utah	41	Iowa	44	Illinois	404
Washington	99	Nebraska	23	Kentucky	19
Oregon	79	Wyoming	2	Tennessee	21
		Colorado	76	Alabama	38
		Kansas	19	Mississippi	10
		Missouri	114		
		Oklahoma	7		
		New Mexico	4		
		Arkansas	8		
		Louisiana	22		
		Texas	31		
Total Members	512		452		990
Percent of Total	8.8%		8.6%		19%
Proportional number of Managers	1		1		2

It is a general custom, founded on the love of equality (so dear to the American mind), that all parts of an organization shall have an adequate representation in its government.

Reckoning representation on this basis, of the three great sections indicated, the Pacific Coast taken as all the States lying west of the continental divide should have one manager and two directors, and the country between the mountains and the river is also entitled to the same number.

This huge section with over a thousand members, though entitled to two managers, has none.

The great and rich section lying between the Mississippi and the Pittsburgh meridian, with nearly a thousand members, has one manager, when it should have two, and two directors when it should have eight.

For some years past each of these three sections has been entitled to a representative on the directing body, but there has been no more than three so far from the trans-Mississippi region.

On the theory that half a loaf is better than no bread, the portionless folk of the far western and coast regions are worse off than their under or half-represented brothers in the middle west.

The selection of managers according to geographical distribution of the membership is an attractive plan, but there are many reasons which have often been cited against it, and some of them have real weight. It has often been urged that it is impossible for managers from the far West to attend the monthly meetings of the board, which is a detriment to the latter's efficiency. It is true that an enormous distance separates them from the center of mass of the electrical fraternity. On the other hand, it must be granted that managers from the far West can occasionally attend, and even when absent can communicate their wishes to the attending members. *The important thing is not so much to have a physical body present at the meeting as to have a thinking brain in the West in close touch with the membership in that section.* If the geographical center of membership of the Institute shall ever move to the Middle West, we predict, in the full realization that prophecy is dangerous, that the meeting of the board will be held in Chicago or St. Louis.

It is sometimes said that a number of the managers represent large commercial interests which are national in their scope, and that therefore these members of the board represent more truly by reason of this fact. But we hardly believe that there is any general acceptance of this theory. There is no reality in it, and it is absolutely opposed to the spirit of the organization of the Institute, which is essentially democratic in character.

The western members will be able to get their share of representation by a little active teamwork on their own account. The constitution of the Institute is a model of clearness and careful provision has been made in it to enable any representative group to get together and put up their man. After that, all that is necessary is for uniform action among the members in the region interested. The obstacle to this has been the vast distances of the western cities from each other and the intense life, centering in each community. Immersed in their own affair, it has been simply another case of no one to take the first step. In this connection it is curious to note that the same indifference to the details of the government seen in larger and less intelligent bodies, is in evidence in the Institute. Less than one member in twenty takes the trouble to cast a nominating vote. The entire electing vote is less than the combined membership of the two smallest groups tabulated above. Under the present conditions, if these members were to act all together, they could elect the entire management.

The time for the annual election of officers is drawing close, and it is hoped that this matter will not be lost sight of. In connection with the desire that our brilliant confraternity on the unrepresented coast may "come into its own," we note with pleasure a movement for nominating to office one of the ablest of Californian engineers. The name and fame of this gentleman are too well known to need mention here. His interest in the Institute and his work as Chairman of the San Francisco section has been of the sort that enable us to congratulate the official body on the prospect of his accession.

We bespeak for him a hearty support from those who believe that justice and equity demand a better representation of their fellow-members around on the sunset side of the continent.

The Unit Cost

In an engineering undertaking the unit of cost is the bridge, or bond, of union between the physical and financial wings of the structure. All of the fore and aft figuring starts from, and harks back to the unit of output whether the sum is a static quantity such as a ton of finished steel or a dynamic quantity such as a kilowatt-hour.

In recent years, when the science of cost-keeping has been brought to a point of refinement and accuracy undreamed of 25 years ago, when by improved record and filing systems, the innumerable component costs that make up the total of any complex piece of modern machinery, such as a turbo-generator, for example, are all kept with unerring accuracy and are available for reference at a moment's notice, publication of cost data has come very much to the center of the view. Modern standard works and the files of the engineering and trade journals bristle with long columns of cost figures of every conceivable factor that enters into the subject under discussion. Even books for use in the schoolrooms and laboratories show that the importance of the financial element is now grasped by those who devote their energies to this field, and they give an amount of cost data unknown and unthought of ten years ago.

Withal, it is to be noted that there is yet much looseness in the way costs, and especially unit costs, are handled. Animated discussions arise on the "cost per kilowatt-hour" of the output of a given plant, without the sign of a qualification as to the kind of cost referred to. Moreover, references to the total cost of unit are often made in a misleading way. It is especially apt to occur in the analysis of the expenses of a plant, and unless properly checked may lead to unexpected results. A case in point follows: A leading commercial concern, operating an isolated plant of about 1500 boiler h.p. capacity within 50 miles of New York, received cost figures on the operation of its plant for a certain month and they looked somewhat like this:

Salaries	$350
Wages	2,125
Coal	4,372
Water	705
Oil and Waste	27
Supplies	41
Repairs	110
Interest	530
Insurance and Taxes	63
Depreciation	247
Total	$8,570

Total output in Kilowatts, 357,000.
Total cost per kilowatt, 2.4 cents.

The owners did not feel particularly well pleased with these results. They were aware that John Jones, who operated a similar plant not far off, was getting his power for a similar total cost of two cents per kilowatt-hour, and they wanted to at least approximate that performance in their own plant.

Accordingly after months of hesitancy and inquiry, a consulting operating engineer was called in to undertake the reorganization of the running of the plant. The consulting operating engineer immediately got very busy. His course of action was along two general lines. He sought first to diminish the cost of power production; second, to decrease the waste in power consumption. Starting in the boiler-room, he first cut the length of the working day by 25 per cent., and introduced a careful system of recording coal, water and supplies. He coached the firemen in the best method of firing and making a good showing in the records. He awakened a spirit of emulation and intelligent pride in the work. He saw to it that the boilers were kept clean and tight, and that the setting was in good shape.

In the engine-room and throughout the plant he went after the leaks and loads. Indicator diagrams were taken, valves were reset where necessary, and all leaks seen and unseen in the system were stopped as far as possible. The load factor of the different machines was looked after and brought up to the highest possible value. Improved types of lamp and other apparatus were adopted where possible. Waste in supplies and repair material was eliminated, and everyone's interest in his share of the work was quickened.

By means of these and other measures that need not be here set forth in detail, he actually succeeded in cutting down the kilowatt-hours used per month from 357,000 to 253,000, a reduction of nearly 30 per cent., and also reduced the total steam consumption per kilowatt-hour from 37 lb. to about 30. After several months of missionary work, the consulting operating engineer thought he was ready for a show-down. By this time a complete year had gone around, and the table for the same month whose figures were given above was duly prepared and is given:

Salaries	$350
Wages	2,125
Coal	3,338
Water	418
Oil and Waste	19
Supplies	37
Repairs	183
Interest	530
Insurance and Taxes	63
Depreciation	247
Total	$7,310

Total output in kilowatts hours, 253,000.
Total cost per kilowatt hour, 2.88 cents.

The first thing that struck the management was that the unit of cost was greater than before by .48 of a cent, an increase of 20 per cent. The elements of the combined costs in the two cases compared as follows:

Total operating cost, exclusive of wages and salaries	$5,255	$3,995
Total operating cost	7,730	6,470
Total of fixed charges	840	840
Total operating costs per kilowatt hour, cents	2.16	2.66
Total cost per kilowatt hour	2.4	2.88

In this instance it is to be noted that although the length of the working day was cut from 12 to 9 hours, the total paid out in wages remained the same. This was achieved by improving the efficiency of the better men and displacing the inferior.

As the total of a bill is the point that fixes the owner's attention, and the net decrease in the total amount of money paid out for the month was $1260, a reduction on the operating costs of over 16 per cent., there was no disposition to find fault with the fact that the cost per unit of output was raised as noted above.

The gist of the matter is that the plant is underloaded and that the reduction of waste in the use of power was of greater relative weight than the economies effected in the cost of its production.

The Sovereignty of Water Power

Since the early days of human society the life of the community has centered about the fountains and streams. By the shores of the great rivers in the milder climates of Asia and Africa the first great civilizations grew to maturity, and in the course of time came to fix and establish law.

Among the first laws of which knowledge has come down to our times are those regulating the rights of the State to its waters, and we believe it to be the fact that throughout the entire world these rights are of substantially the same nature. The control of all navigable rivers and lakes is vested in the central government, that of the lesser streams and water courses in the local authorities. Under the oldest forms of Latin law all running waters are under government control, but the idea in the North of Europe was that the local community should control its own waters, subject, of course, to the right of the general government.

In the United States the law states that Congress shall exercise constitutional control over all navigable waters, and the question as to the navigability rests with Congress. In Mexico the Latin custom prevails, and there is no need to determine navigability.

Water legislation in the various States forming the Union has been as profuse and often as footless as on many other subjects. The defilement of our fair streams by the criminal alliance of carelessness and greed that has led to so much of the national waste is not the least of our sins against our fatherland. Too long have the misusage and neglect of the public been scarcely less injurious to the actual streams than to their fountainheads.

It is with great satisfaction that we have noted the stirrings of public conscience in this matter. Though slow, the arousing from the stupor and in-

ertia of neglect is none the less real, and will go on. Evidences of its movement are showing on every hand.

Last month a bill was introduced into the Legislature of New York State which proposes a constitutional amendment to be known as Section 7A of Article 7 of the Constitution of the State of New York.

The new amendment reads as follows:

"The people of this State in their right of sovereignty do possess the original and ultimate property of the waters in and about all rivers, lakes, streams and tributaries within the State of New York, and it shall remain the property of the State and under its management forever.

"§2. The State shall not lease or otherwise dispose of the waters of any river, lake, stream or tributary for water power for a period of more than ten years, except that the State may lease, contract or otherwise dispose of the waters of the rivers, lakes, streams and tributaries for the purpose of supplying water to the inhabitants of State of New York."

There is no doubt that the public of to-day is at last awake to its interest in the vital matter of the control, preservation and restoration of the forests. This State to-day controls nearly a million and three-quarters acres of public forest land. Other States have acquired, and are acquiring, like imposing holdings. The work of the government in this line is well-known. Now we take it that the forest control and water control are very closely related. The relation is really about that of the late lamented Siamese twins. The conservation and restoration of our shrunken rivers will proceed with and from the reforesting of the hills that rise about the fountain-heads. The great commercial interests themselves, who, ten years ago, were in the front of the riot of waste have learned by actual experience its cost and ultimate ruin. The iron bond of self-interest will tie them henceforth to the wheel of progress. We look to their earnest and powerful co-operation in the work that lies ahead.

Long ago the nations of central and southern Asia and the south of Europe took their tolls from the coming generation. To the operation of the great law anent "the sins of the fathers" may be traced many of the conditions that make the deplorable plight of those lands as we see them to-day. The wisdom of much time has attempted to forecast the future by stating that "history repeats itself." Will it do so in this land and time?

We believe not. Men are alive today as never before. In the matter of water-power only—a minor one as compared with the other stupendous effects of the rainfall on a country's well-being—they know that with care that power will suffice for ages to come. Theoretically the flowing waters of the earth aggregate eight trillions, or 143 h.p. per square mile and five per inhabitant. Utilizable of this are at least five hundred billions or an average of nine per square mile. The value of this resource to the world—and that of our own land is above the average—will insure its guardianship.

To the engineering professions the world will look for its guidance in the preservation of its heritage. As to how they will fulfil the tremendous trust no one who knows them has doubt.

The Patent Court

In the news dispatches for the current month is a brief notice to the effect that the committee powers at Washington have reported favorably on the plan to establish a Patent Court.

Some time ago, after a protracted campaign against the limitations of the present long out-worn system of handling patent cases, the American Bar Association was induced to take up the grievance. The Association drew up a bill providing for a court consisting of five judges, to sit permanently at Washington and try all patent cases.

With the enormous expansion of business of the last fifteen years, the situation in the Patent Office had become so strained that even Congress at last had to act. Of the more than 900,000 patents issued up to date over half have been issued since 1895. In other words, the office has been called on to do as much work in fifteen years as in all its previous history. Moreover, the salaries of the employes were way behind the modern scale. Some of them, it is said, had not been increased for 60 years. The repeated appeals for relief which formed the bulk of the reports of the Commissioner of Patents at last were heeded and recently the force in the office was greatly enlarged, salaries raised to a level more in keeping with the importance of the work done and the space at the disposal of the bureau increased.

The improvements form but a small part of what must be done before the "patent industry," if it may so be termed, is placed on an equitable and efficient basis. The hardship and injustice wrought by congestion and delay in the office is almost infinitesimal beside what has been taking place outside.

The evolution of patent law has followed that of the other branches. Under the effects of the prevailing system the result of the work of a hundred years of patent granting and patent litigation has been to weave an elaborate chain of procedure whose unintentional effect has been to strangle the chances of the inventor.

The government reports tell us that the average male citizen of the United States is in possession of an income of between eight and nine hundred dollars a year.

This being the case, what are his prospects under the present methods of conducting this class of litigation? The weary string of trials, running from court to court, wear out his fortune and patience. A rich corporation, if unprincipled, or a crafy patent shyster can rob him of all the benefits of the invention simply by "lawing him down."

Instances of this process are so well known that almost all of us can recall several. In the electrical field suffice it to mention such classic cases as the Tesla induction motor patents which were afflicted with chronic litigation until they expired. The Stanley transformer patents and those of the Van Depoele underrunning trolley are also in point. So widespread has the disease become that there are many observers who think that it is deliberately bred and spread by the highly organized and astute body of gentlemen whose incomes its prevalence enormously increases.

At all stages of the process the patent case is a stranger within the gates of the temple of justice. Before each Federal Judge the patent cases form but a small portion of the total. Sandwiched between postoffice robberies and applications for receivership comes the highly complicated technical patent dispute to receive justice. The result is usually a strain on judge and justice alike.

Modern technical conditions have reached a stage where the brain of one man can no longer compass their tremendous scope. The technical judge, learned alike in the patent law and the many branches of industrial science, is as certain to evolve as was the specialist.

The industries based on patent rights are worth many millions. The patent office itself takes in $2,000,000 a year in round numbers. It is high time that its dignity and value receive their full recognition. The creation of a patent court is a step already too long delayed. An authoritative and final tribunal sitting, first and last, on all patent cases will mean swift and, let us hope, sure justice alike to the inventor possessed of small means and to the corporation with its millions. Its establishment, affecting as it does a field of action whose intensity is distinctively and peculiarly of our country, will be heartily welcomed by the whole American people.

Transformation Wrinkles

H. B. GEAR and P. F. WILLIAMS

Commonwealth Edison Co., Chicago

THE use of various distributing primary and secondary voltages, single, two and three-phase systems, gives rise to situations which require the distribution engineer to resort to various unusual devices to fit these together with standard apparatus.

A breakdown in an industrial plant may make it necessary to get quick action in furnishing power from the central-station system. The ability to make such connections promptly may be a factor in impressing the industrial concern with the advantages of drawing its supply from the distributing system permanently. Or conditions may arise when it becomes desirable to be able to render service to a consumer who has been securing his services from a competitor on a different system.

Such situations cannot always be easily met, since a change from the direct to alternating current or other conditions which necessitate a change in motors involves an expense which is likely to be prohibitive.

However, there are situations which can be met with comparative ease by the use of standard apparatus, which should be sufficiently familiar to the engineer to enable him to turn readily to his data book to get the necessary details as to connections, voltages, capacities of transformers and such information as he is in urgent need of. Some of the combinations and devices which are most likely to arise, as well as others which are unusual are, therefore, presented herewith.

The connections of standard line transformers are shown in Figure 1(*a*) and 1(*b*) for convenient reference. Such transformers are made with two primary and two secondary coils. This permits their use on 2200-volt circuits, as shown in Fig. 1(*a*) or 1100-volt circuits as shown in 1(*b*). Similarly the secondary may be connected for 110 volts to supply lighting or power on the two-wire system, as in 1(*a*) or for lighting or power on the three-wire Edison system at 110-220 volts, as in Fig. 1(*b*).

Systems operating at approximately 2080 volts sometimes use a standard transformer having windings for 1040-2080 to 115-230 volts. Such transformers are commonly called 9 to 1 in distinguishing them from 1040-2080 to 104/208, which are known as having a ratio of transformation of 10 to 1.

The primary connections are changed from 2200 to 1100 by means of a connection block inside the transformer case. The terminals of the secondary coils are brought outside the case in such proximity that they are readily put in parallel by joining the adjacent terminals as in 1(*a*). Likewise for 220-volt operation the two middle terminals are connected together thus forming the neutral of the three-wire system. Connection blocks are not used because of the large current carrying capacity required on the secondary side.

The connections for three-phase, three-wire and four-wire systems are shown in Figs. 1(*c*) and (*d*). A simple way to remember the three-wire connection is to bear in mind that when all the transformers are connected in series in a closed circuit, a tap is made from each phase wire to the common point between each pair of transformers. This is the well-known "delta" connection, so called

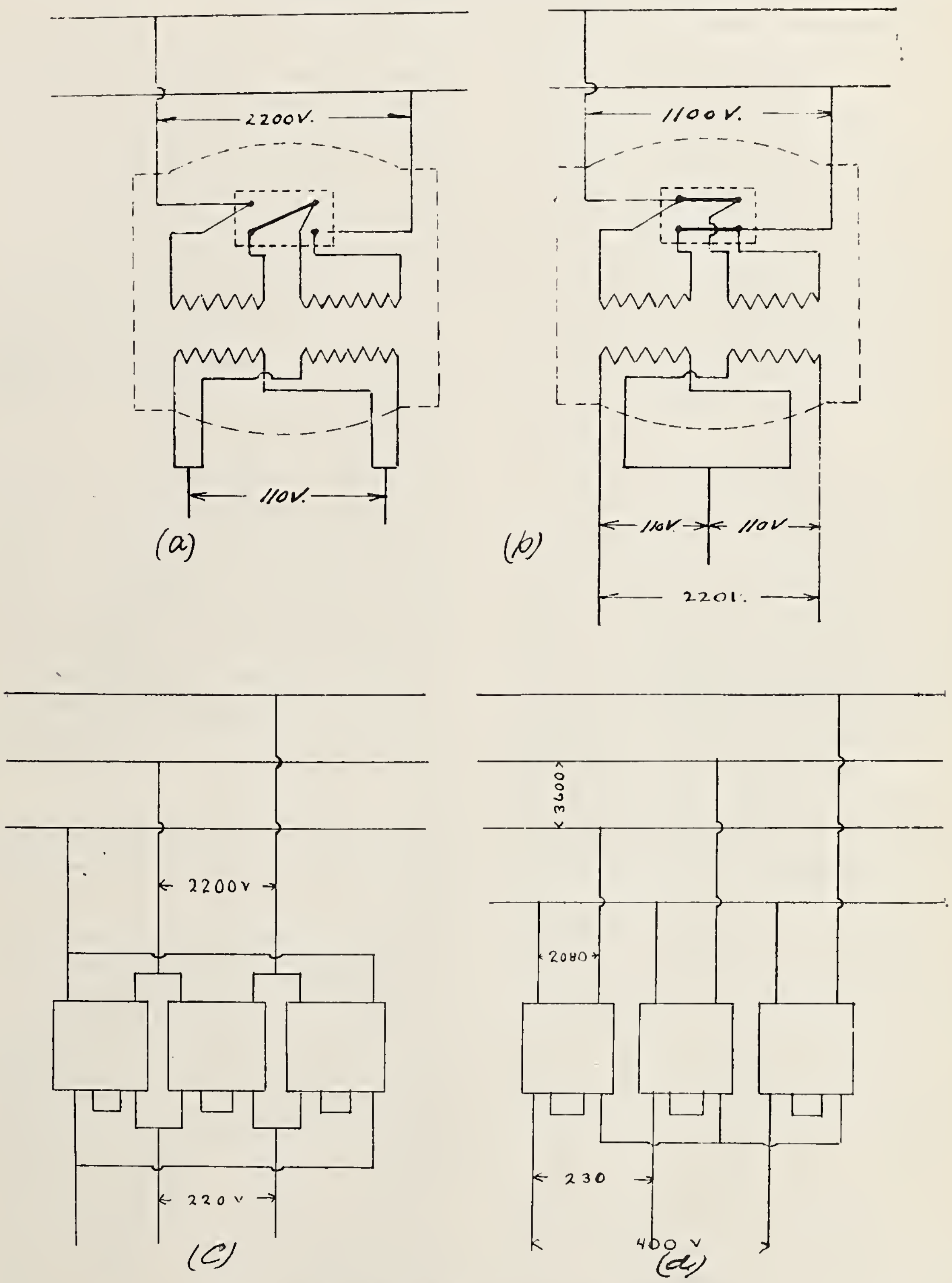


Fig. 1.—SINGLE AND THREE-PHASE CONNECTIONS

because the triangle by which it is represented resembles the Greek letter delta.

The connection in Fig. 1(*d*) is easily recalled by bearing in mind that all right-hand terminals go to the phase wires while all left-hand terminals go to the neutral or vice versa.

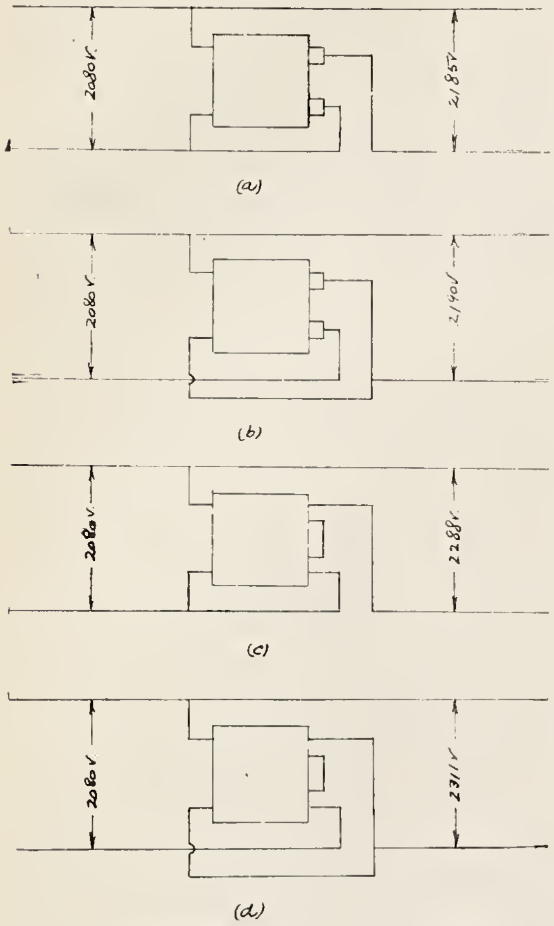


Fig. 2.—SIMPLE BOOSTER CONNECTIONS

This connection is called the "Y" or "star" connection because of its resemblance to these forms when represented in a polar diagram.

The secondary connection may be made either delta or Y in either system. The Y connection gives 1.73 times the voltage of the delta and is therefore a useful device to resort to in giving 400-volt service from 230-volt transformers on a three-phase system. It may be taken advantage of in many other ways since it only requires the use of about 15 per cent. additional pressure to make a ratio of 2 to 1.

In combining transmission systems it is often possible to use existing transformers by merely changing from delta to Y connection, or vice versa.

Where it is necessary to raise or lower pressure by a fixed percentage, as is necessary when transformer ratios are not quite right, this may be accomplished by a transformer used on a booster; that is, a transformer so connected that the primary main line is in series with its secondary. This raises the primary pressure by the amount of the secondary voltage, thus boosting the pressure of the circuit, as shown in Fig. 2.

For instance, on a long, single-phase, 2080-volt lighting branch which has so much load that the pressure drops more than the normal regulation of the feeder will care for, a 110-volt transformer inserted in the line as a booster will raise the primary pressure 110 volts. This raises the secondary pressure on all the transformers 5.5 volts. In the case of the 440-volt service supplied by star-connected 230-volt transformers a 10 per cent. booster in each phase raises the normal pressure of 230-400 volts to 253-440 volts.

Various other applications of the booster arise in every large distributing system, some of which are included in certain special cases considered hereinafter.

With the secondary connected in the reverse order the transformer becomes a choke, depressing the line pressure instead of raising it. This is a useful device in some schemes of connection, where a little less pressure is desired.

The proper connection of the secondary for booster or choke must usually be determined by trial for any given type of transformer, but once determined any transformer of the same type may be connected in a similar manner. The connections of Fig. 2 are those for the transformers of the principal makers.

The connections for a simple booster are shown in Fig. 2(*a*), the line pressure being raised from 2080 to 2184 volts, or five per cent. The connection of 2(*b*) is that for an augmented booster, in which the line pressure is raised from 2080 to 2190, because the primary of the booster is connected across the line on the far side, and the booster is boosted, as well as the line. This gives an increase of 5.5 per cent. in the line pressure.

Fig. 2(*c*) shows a 10% simple booster and 2(*d*) an augmented 11.1% booster.

The corresponding connections for a 5% choke are shown in Fig. 3(*a*), a 4.75% choke in 3(*b*), a 10% choke in 3(*c*) and a 9.1% choke in 3(*d*).

It should be noted that the transformers used in these illustrations have an interchangeable 10 or 20 to 1 ratio of transformation, and that these percentages apply only to boosters having this ratio of transformation. If boosters having a ratio of 2080 to 115-230 are used the percentages are increased about 10%. Figure 2(*a*) becomes 5.5%, 2(*b*) 6.05%, 2(*c*) 11.1% and 2(*d*) 12.2%. Similarly the chokes in 3(*a*) would be 5.5%, 3(*b*) 5.24%, 3(*c*) 11% and 3(*d*) 10%.

There are certain precautions which should be observed in the installation of boosters to protect them from injury. The booster secondary is in series with the line and current is drawn through its primary winding in proportion to the load on the line. If the primary of the booster is opened while the secondary is carrying the line current the magnetization of the transformer is greatly increased and the booster acts as a choke coil in the main circuit. This causes a large drop of pressure in the booster, imposing upon its secondary winding a difference of potential of several hundred volts. The primary coils likewise generate a pressure 10 or 20 times that in the secondary, and the insulation of a 2000-volt transformer is subjected to a potential of 10,000 to 20,000 volts or more, depending upon the load carried by the main circuit at the time.

In case it is attempted to use a fuse in the primary, the blowing of the fuse creates this condition and the arc holds across the terminals of the fuse block until it burns itself clear. It has often been observed that where boosters have been "protected" by fuses in this way, the transformer has burned out shortly after the blowing of its primary fuses if not at the time.

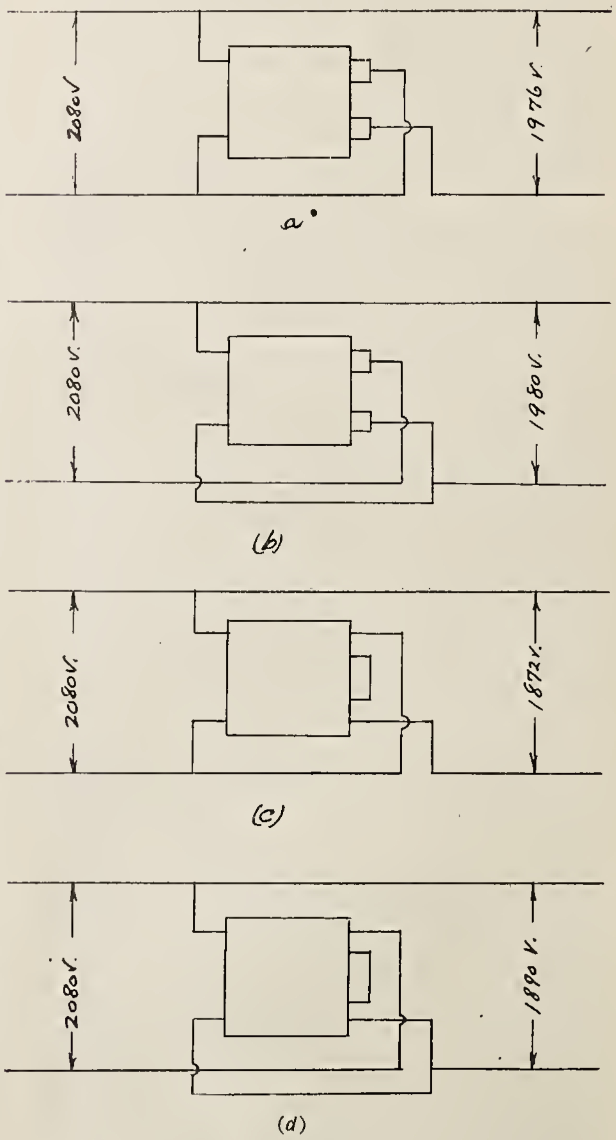


Fig. 3.—SIMPLE BOOSTER CONNECTIONS

The preferable manner of connecting or disconnecting a booster is to open the main line before putting it in or out of circuit. This is sometimes undesirable, however, and if the service on the line cannot be interrupted, or if it is desired to switch the booster

in or out at certain times, this may be accomplished by the use of a series arc cutout, connected as shown in Fig. 4.

The operation of the cutout simultaneously opens the primary and short circuits the secondary of the booster. The switch must be of a type having a positive action, so that arcing will not damage its contacts at the moment the secondary is short-circuited. The arc cutout must have sufficient carrying capacity to carry the main line current when the booster is shunted out and standard series arc cutouts should not be used where the line current is likely to be over 20 to 25 amperes.

When the augmented booster is used the terminal of the primary winding of the transformer which goes to the cutout should be connected to that terminal of the cutout which is shown as not being in use in Fig. 4.

The connections for boosters in a two-phase system are similar to those shown in Figs. 1 and 2 for the single-phase system. Where three-wire two-phase feeders are used the boosters are looped into the outer wires and the pressure is taken from the common wire.

The use of boosters in a delta-connected three-phase system is not so simple as is the single-phase application. The booster is looped into the line wire and pressure is taken for its primary coil from an adjoining phase wire, as in Fig. 5(*a*). The insertion in the line of the booster voltage, however, affects two phases as shown diagrammatically in 5(*b*), which illustrates the effect of a ten to one booster put into the "C" phase only. When boosting, the pressure from A to C is raised 110 volts, while B to C is raised 208 volts, the pressure coil of the booster being connected from B to C.

The effect of a booster in each phase is seen in Fig. 5(*c*) in the larger dotted triangle, and the small triangle in the same figure shows the effect of a choke in each phase.

The boosting or choking effect when various booster transformer ratios are used in one, two or three phases are expressed in percentages

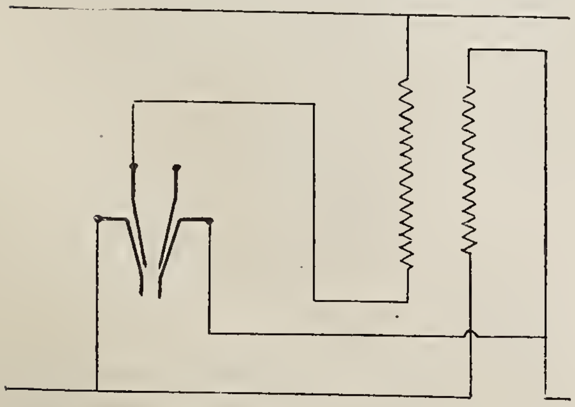


Fig. 4.—SERIES ARC CUT-OUT CONNECTIONS

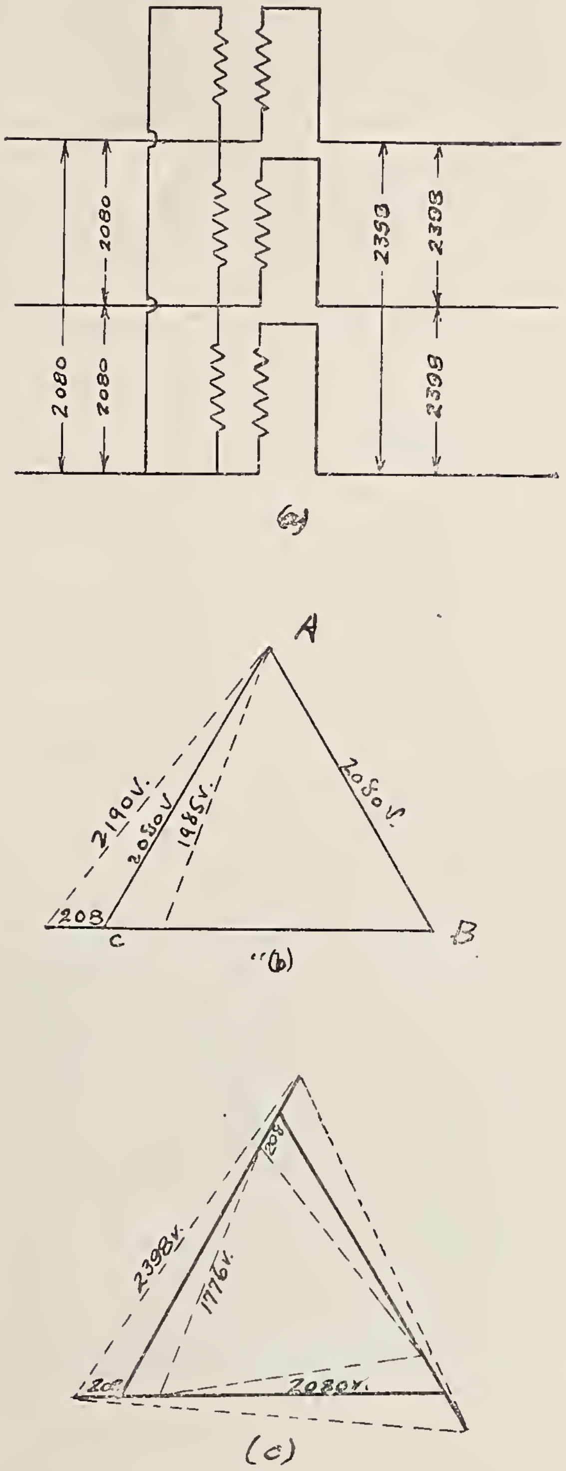


Fig. 5.—VOLTAGE DIAGRAMS

of the primary voltage in the following table:

BOOSTING.

Ratios.	10 to 1			20 to 1			9 to 1			18 to 1		
Phases	A B	B C	C A	A B	B C	C A	A B	B C	C A	A B	B C	C A
A	10	0	5	5	0	2.65	11	0	5.8	5.5	0	2.9
A and B	15.3	10	5.3	7.65	5	2.65	16.8	5.5	5.8	8.4	2.75	2.9
A, B and C	15.3	15.3	15.3	7.65	7.65	7.65	16.8	16.8	16.8	8.4	8.4	8.4

CHOKING.

Phases.												
A	10	0	4.6	5	0	2.3	11	0	5	5.5	0	2.75
A and B	14.6	10	4.6	7.5	5	2.3	16.06	11	5	8.03	5.5	2.75
A B and C	14.6	14.6	14.6	7.3	7.3	7.3	16.06	16.06	16.06	8.03	8.03	8.03

TABLE OF BOOSTING AND CHOKING EFFECTS

The introduction of 110-volt tungsten or other high efficiency lamps into a 220 or 440-volt system in an industrial or other large plant may be accomplished quite readily by the use of standard transformers. The connections in Fig. 6(*a*) are those for the use of two-wire, 110-volt distribution on a 220-volt system, the load being assumed at 20 amperes. The distribution of current in the windings is indicated by the figures and arrow heads. It will be seen that the transformer capacity required is equal to the load when a standard transformer is used.

When the lighting is distributed on the three-wire 110-220-volt system, the transformer carries only the unbalance of current in the two sides of the system, as shown in Fig. 6(*b*). In this case the unbalance is five amperes. The transformer carries 2½ amperes at 220 volts, and need be only large enough to carry the largest unbalance which is likely to occur. The primary winding is left open and is not used.

In a 440-volt plant where 110-volt lighting is desired it may be secured from standard transformers, as in Fig. 7. This requires the use of two transformers in series on the 220-volt side and in parallel on the primary side. It is important that the primaries be in parallel, as the other transformer will act as a choke to the lighting current which must pass through it if they are left open as in the 220-volt system.

The lighting distribution in a 440-volt system is preferably accomplished by the three-wire 110-220-volt system as this requires transformers of capacity equal to the load, while two-wire 110-volt distribution requires that the transformer on the side on which the lights are connected have a capacity of 1.5 times the load, while the other one must carry half the load, making the total capacity twice the load.

It would be possible, of course, to run a five-wire system or two three-wire systems and so reduce the transformer capacity to that of the unbalanced load, but this would not often justify the increased complication of the wiring which would be occasioned by such an arrangement.

Combinations may be made on the primary side of standard transformers in a manner similar to those above outlined for the purpose of securing intermediate or higher voltages from the supply system. 1040, 2600 or 3120 volts can be gotten from a 2080-volt system by the use of two transformers in series on the primary and in multiple on the secondary. These connections are shown in Fig. 8(*a*), (*b*) and (*c*) respectively.

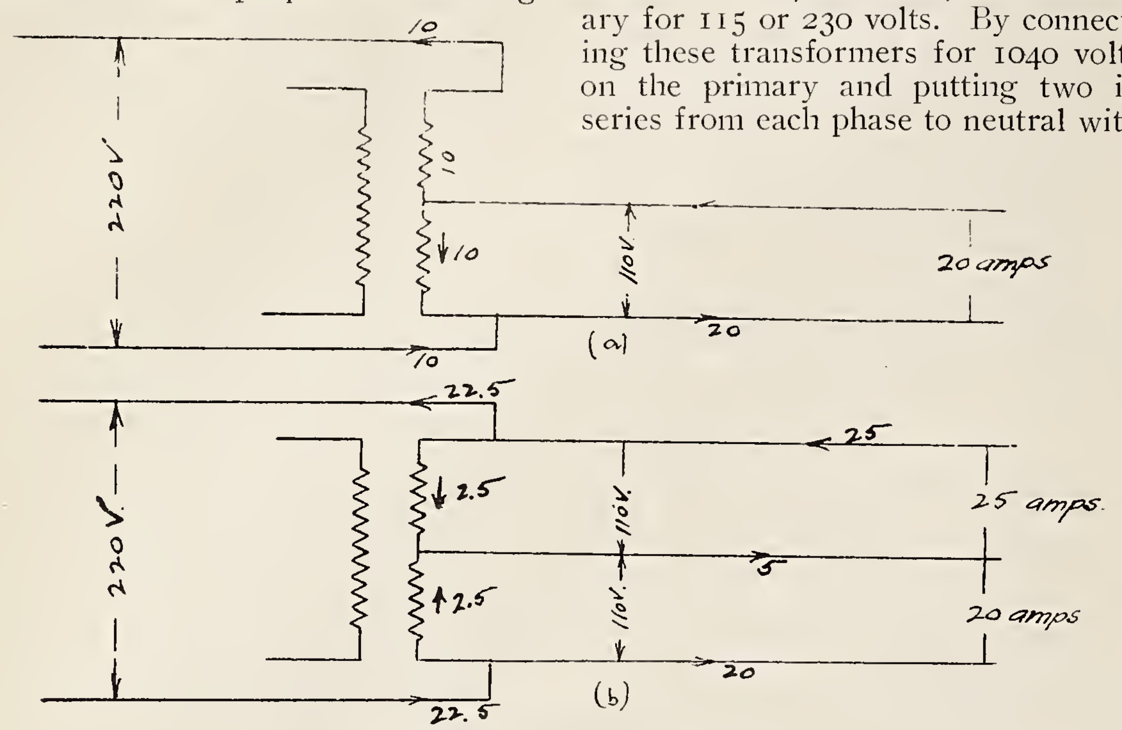


Fig. 6.—110 VOLTS FROM 220

Various other combinations are possible by the use of more than two transformers, by which higher primary or lower secondary and other intermediate voltages may be derived.

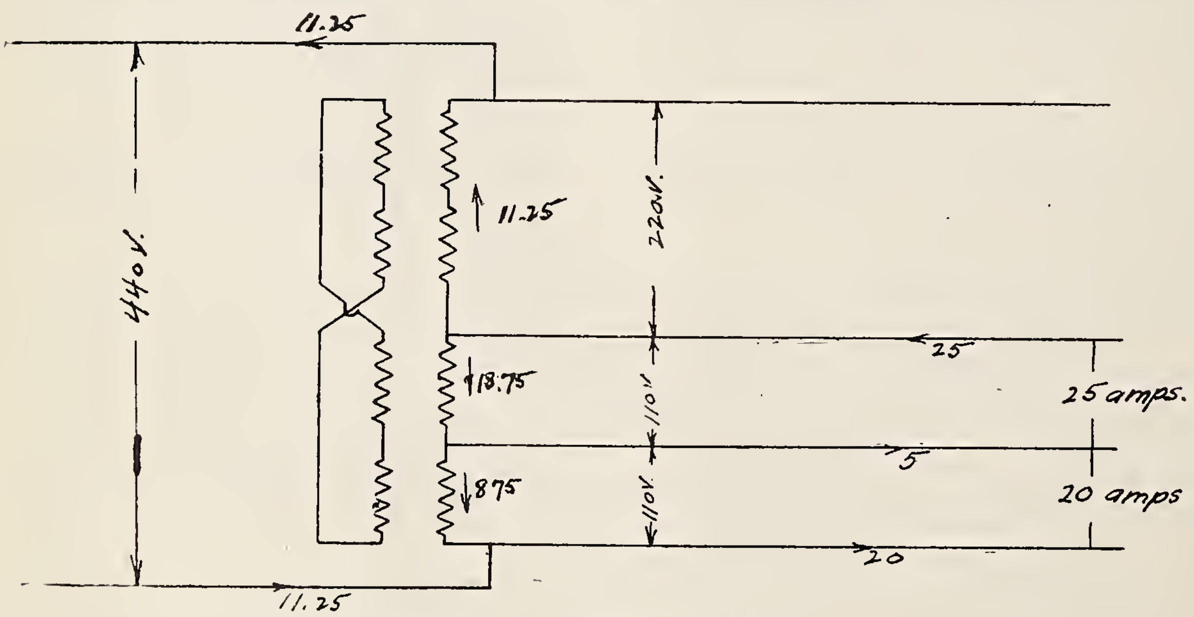


Fig. 7.—110 VOLTS FROM 440

One application of the foregoing general principles serves to illustrate the value which such devices may have under certain conditions.

An installation consisting of a 300-kw. 2080-volt three-phase motor was to be supplied with energy from a four-wire Y connected system operated at about 2160 volts between phase and neutral, or 3740 between phases. The only transformers available for the purpose were six 50-kw. core type transformers, with primary coils wound for 1040 or 2080, and secondary for 115 or 230 volts. By connecting these transformers for 1040 volts on the primary and putting two in series from each phase to neutral with secondaries in parallel, it was possible to tap the motor circuit off at half the line pressure. The line pressure being but 3740, the additional amount required to get 4160 was secured by the use of a 9 to 1 booster in each phase.

The connections are shown in Fig. 9 in diagrammatical form, without the secondary connections, and as carried out physically in Fig. 10.

The expense incurred for transformers for small three-phase power service makes desirable in many cases the use of schemes of connection by which three-phase secondary pressure may be derived from two transformers. Two schemes of connections are possible for this purpose, one known as the open delta and the other as the T connection.

The open delta connection for a three-wire system is shown in Fig. 11(*a*). This is merely an ordinary delta connection with one transformer left out. A simple rule by which this connection may be kept in mind is that both primary and secondary are connected in series as if it were a three-wire Edison system. The middle wire of the line goes to the middle point between the transformer on both primary and secondary.

In order to reverse the rotation, the two outside wires must be interchanged on the primary or either two of the three on the secondary side.

Fig. 11(*b*) shows the open delta connection for a four-wire three-phase system. In this case the primary is connected so that both right (or left) hand terminals are taken from the neutral wire. The other two terminals are taken one each to any two-phase wires. To reverse rotation on the primary side the phase wires should be interchanged. On the secondary side any two wires may be reversed.

The open delta connection requires 15.4% more capacity in the transformer coils than three transformers. That is, if 3-5-kw. transformers are fully loaded by a given installation, they may be replaced by an open delta set of two 7½-kw. transformers, but the coils of the 7½-kw. units will be overloaded 15.4 per cent. This is evident from an example. Assume that in a three transformer installation the current in the secondary line is 17.3 amperes. This places a load of 10 amperes on the transformer secondary coils. At 200 volts this is 2 kw. per transformer or 6 kw. in all.

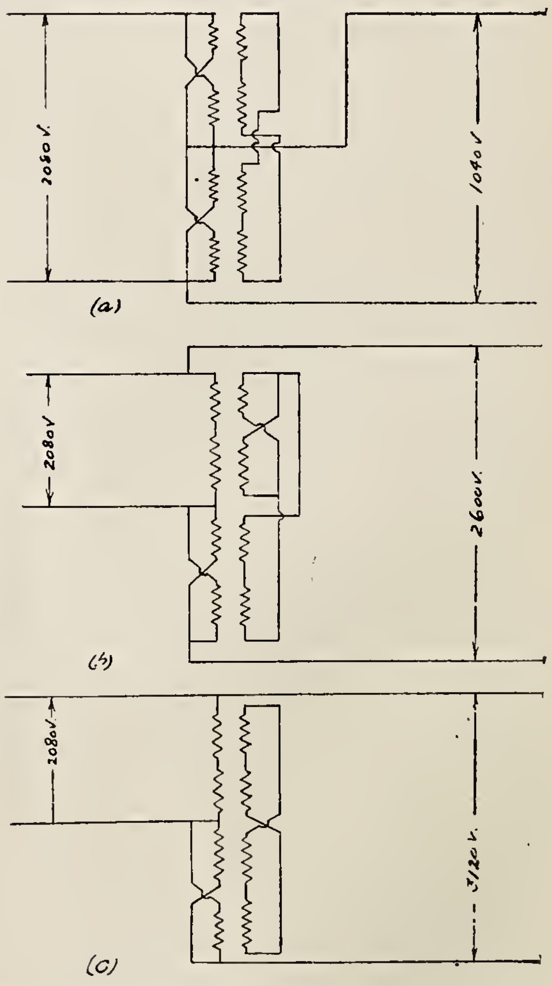


Fig. 8.—HIGH-VOLTAGE CONNECTIONS

If two 3-kw. transformers were put in to replace the three 2-kw. units, the capacity of the secondary coils would be 15 amperes. But with the open delta connection the current in the secondary coil is the same as the current in the line and the 15-ampere winding must carry 17.3 amperes or 15.4 per cent. overload.

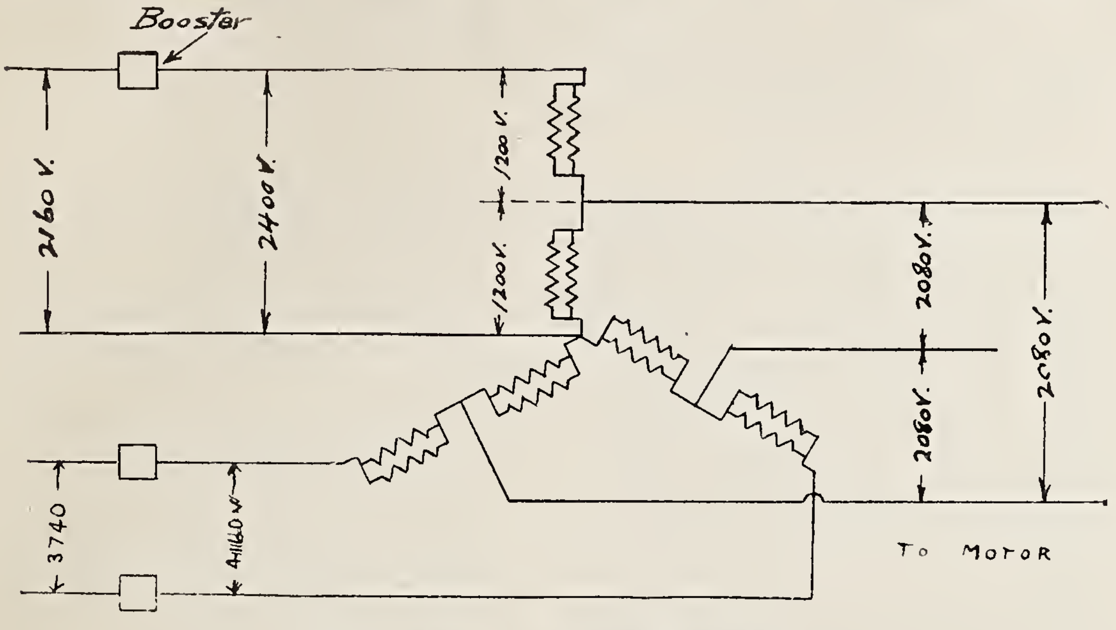


Fig. 9.—SPECIAL CONNECTION DIAGRAM

With a three-wire three-phase system, power service may be given by the use of two transformers with the T connection on both primary and secondary, as shown in Fig. 12. The current overload is 15.4 per cent., as with the open delta connection. This scheme cannot be used with standard 2200-volt transformers on a four-wire system as the delta voltage is 3800. It cannot be used by putting two transformers in series as the principle of operation requires that the current passing to the transformer at the left, in Fig. 12, from the other transformer, divide and pass each way from the mid-point, so that the magnetic field of one balances the other. When two transformers are used across one phase, the magnetic circuits are separate and the balancing reaction cannot take place. The connection to the middle point of the primary is not brought outside the case in standard transformers and it is therefore not often used.

This connection has a slight advantage over the open delta in the three-wire system, as the pressure across the right-hand transformer is but 86.6 per cent. of the line voltage, which reduces the iron loss in this transformer about 15 per cent. The inherent regulation is also somewhat better.

The T connection is used in transforming from three-phase to two-phase or vice versa, as shown in Fig. 13(a).

It will be noted that one transformer must have a tap brought out so as to make the ratio of transformation on that unit from 1906 to 220, instead of 2200 to 220 as in the other unit. As standard lighting transformers are not usually equipped with an 86.6 per cent. tap, special units are required for this connection. This connection may, however, be quite closely approximated by the arrangement shown in Fig. 13 (b), when the transformation is made from two-phase to three-phase. Standard 10 to 1 transformers, one phase of the two-phase supply being choked by two transformers, one connected for 9.0 per cent. choke and the other for 4.5 per cent.

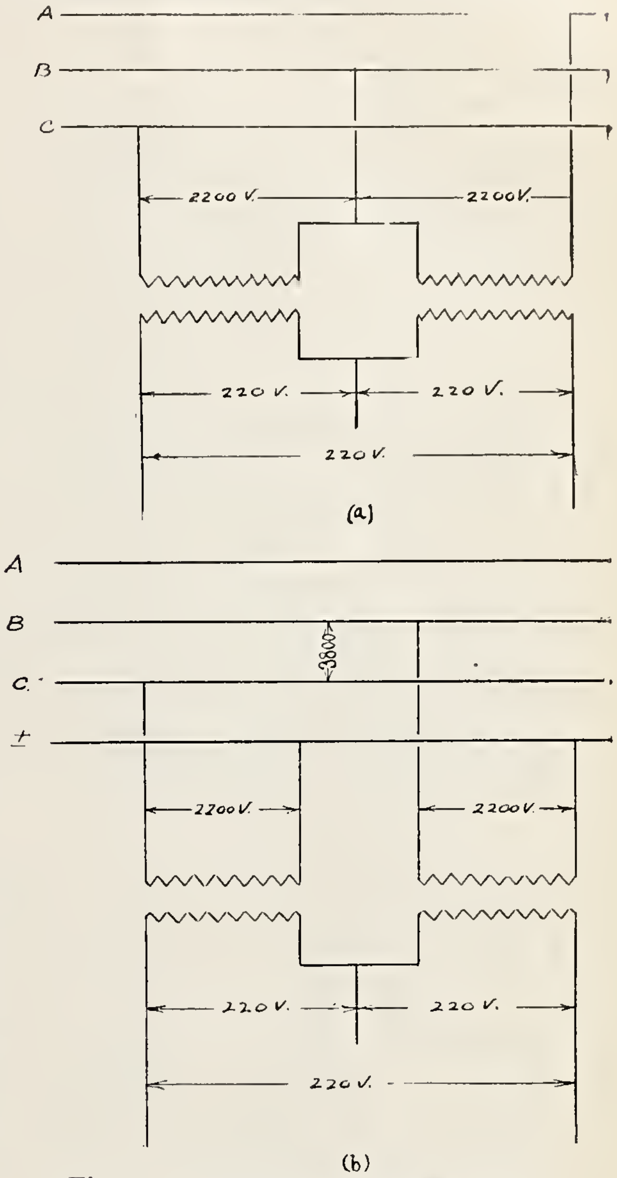


Fig. 11.—OPEN DELTA CONNECTIONS

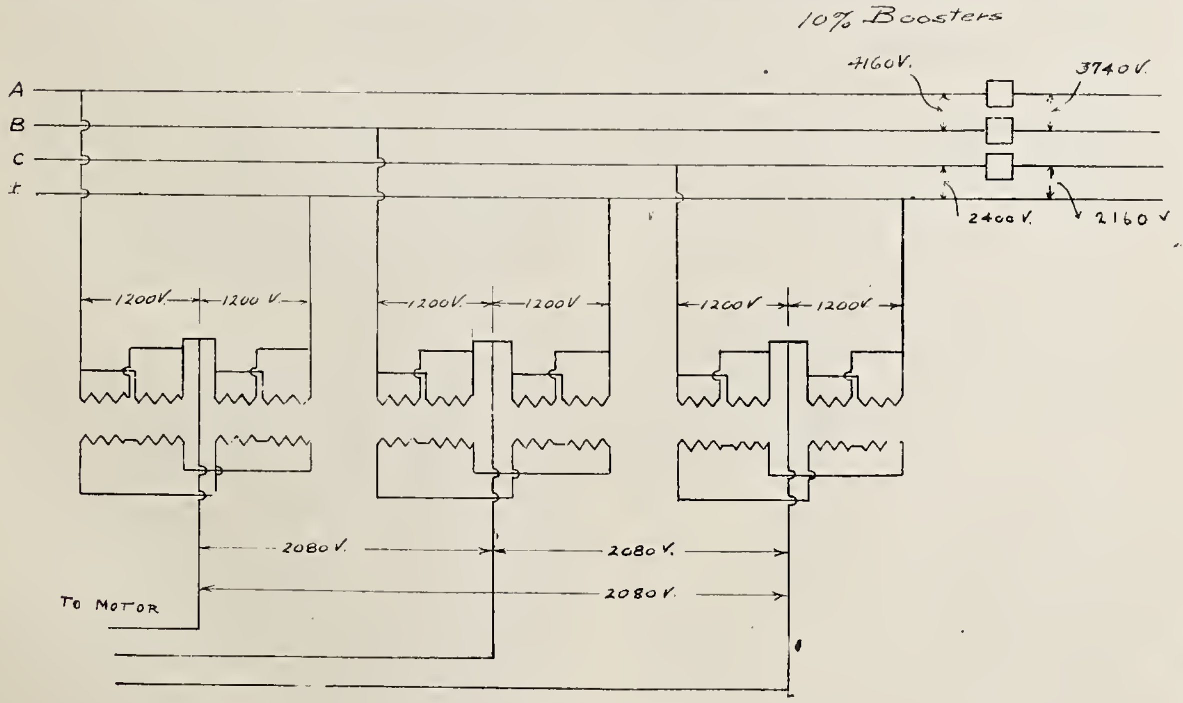


Fig. 10.—SPECIAL CONNECTION

If the pressure desired for the motor service were 230 volts and the primary pressure were 2080 instead of 2200, the left-hand transformer in Fig. 13(b) should have a 9 to 1 ratio. With a 10 to 1 as the other unit, the 9 per cent. choking transformer could be dispensed with.

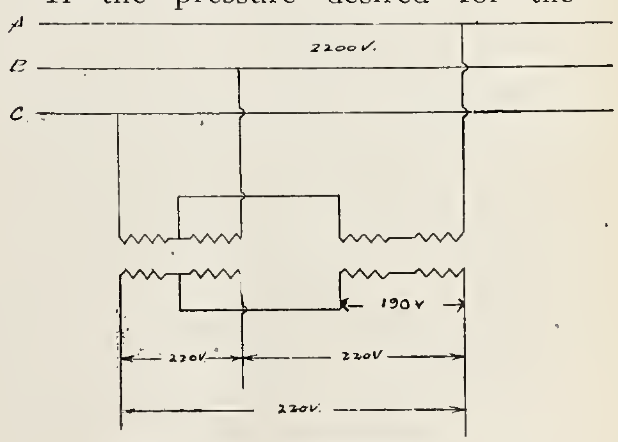


Fig. 12.—T CONNECTION

In transforming from three-phase three-wire to two-phase, with standard transformers, the pressure on the right-hand transformer in Fig. 13 (*a*) must be raised by a booster. With a

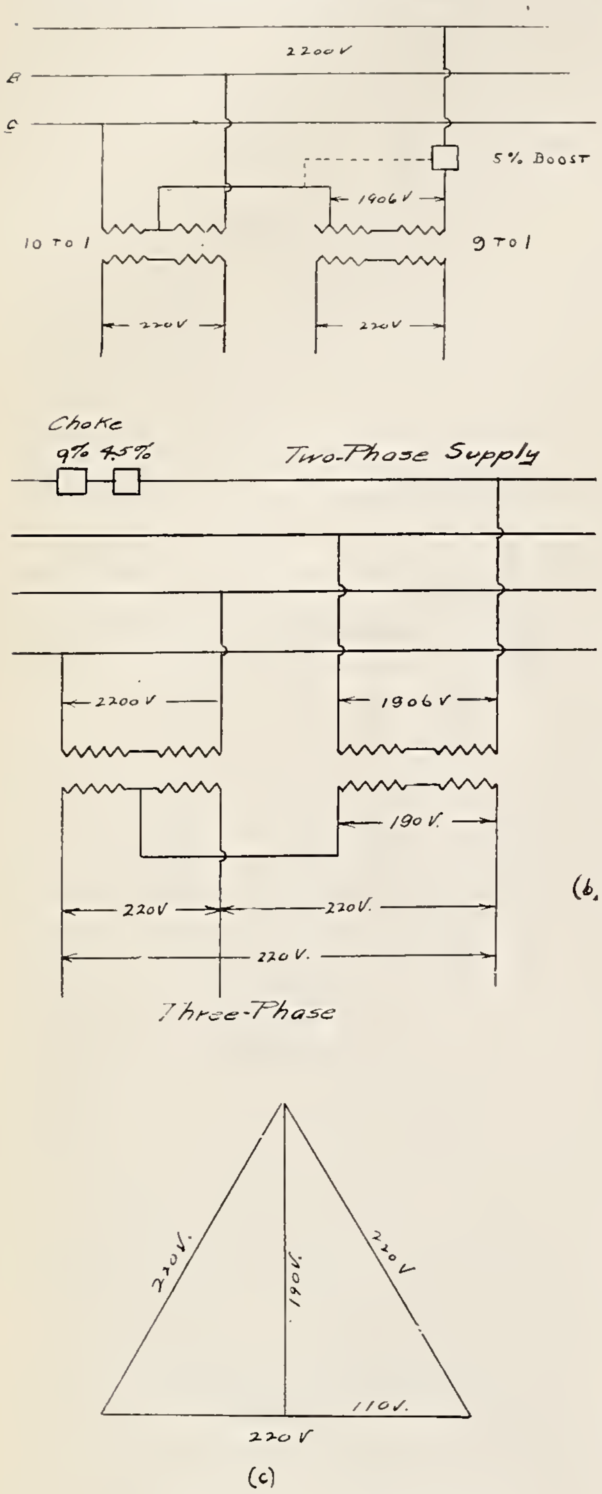


Fig. 13.—T CONNECTIONS

10 to 1 transformer in the left-hand position, and a 9 to 1 at the right, the pressure must be raised five per cent. by a booster. The primary coil of the booster must be connected from A phase to the center of the T connection as shown in Fig 13 (*a*), in order to get the pressure of the booster in phase with the current in the right-hand transformer. If only 10 to 1 transformers are available, the right-hand transformer must be boosted 15 per cent. instead of five per cent. If only 9 to 1 units are to be had, the left-hand transformer must be choked 10 per cent. and the right-hand unit boosted five per cent., to give 220 volts two-phase service.

In deriving two-phase 440-volt supply two sets of transformers may be used, putting them in parallel on the three-phase side and in series on the two-phase side.

It is impossible to derive 440-volt three-phase supply from a two-phase supply, except with 440-volt transformers since transformers will not operate in series on the T-connected side of such a combination.

In deriving two-phase 220-volt supply from a four-wire, three-phase system with standard transformers it is necessary to use three transformers connected as in Fig. 14. The unit at the left is a 10 to 1 connected from one phase to neutral. The two at the right are 9 to 1, connected with their secondary coils in multiple, and are arranged as two limbs of a Y so that 127 volts is required at the transformer terminals to give 220 volts across the outer wires.

The three-phase system is unbalanced by this arrangement, since half the power is taken from one phase and the other half from the other two, making the balance in the proportions of 50, 25 and 25. The capacity of the transformers should also be in these ratios.

It is possible to use 10 to 1 transformers for all, but if this is done, it is necessary to install 15 per cent. boosters in each of the two phases

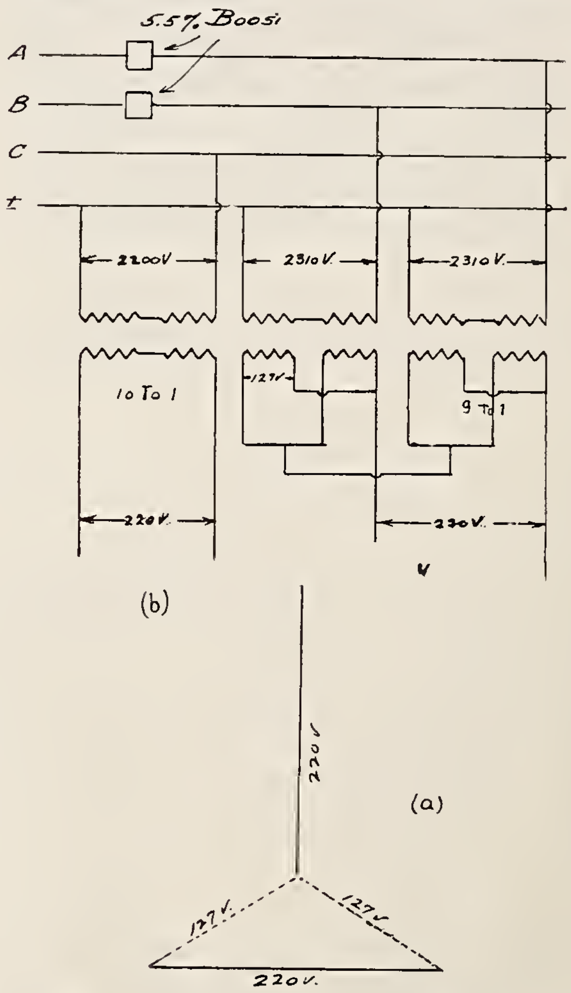


Fig. 14.—TWO-PHASE FROM THREE-PHASE

supplying the right-hand transformer in Fig. 14.

It is not possible to derive a four-wire three-phase system from a two-phase system with standard transformers.

Railway Electrification in Japan

The Japanese government has recently placed four contracts for machinery and apparatus for the railway electrifications about to be made on the imperial government system. The first of these, consisting of three 1000-kw. steam turbines with exciter, switchboard and other power-house appliances, was awarded to the General Electric Company.

The second, consisting of 10 pairs of trucks with 10 sets of 50 horsepower direct-current railroad motor equipment, went to the Siemens-Halske Company of Germany. The car bodies for this equipment are being built in Japan.

The third contract, consisting of two 300-h.p. water turbines direct-connected with 200-kw. alternating-current generators, together with complete exciter, transformer, switchboard and other power-house appliances, was secured by Takata & Company, of Tokio and New York.

The fourth contract, consisting of 12 electric locomotives of about 50 tons each, has not yet been let.

The road to be electrified connects Tokio and several other of the larger cities of Japan. The government is said to have decided to electrify all of the lines about the more important cities of the country.

Railway Projects

The Prussian State Railroad Commission, which has for many years been considering the subject of electrifying of suburban lines, and has equipped those in the vicinity of Hamburg with a single-phase system, has now decided to electrify the entire suburban railroad system of Berlin in the same manner.

The cost of this work will be not far from $50,000,000, and the triumph of the single-phase idea is all the more notable when it is recalled that the first electrification carried out by the Prussian State Railroads was a continuous-current third-rail system in the same city of Berlin.

The Illinois Traction System will change the Bloomington-Peoria line from single-phase to direct-current. This part of the lines of the company has been operated from Peoria, and has been the cause of trouble on account of cars having to run over direct-current city circuits. The line from Mackinaw to Springfield will also be changed over, making an alteration of about 100 miles altogether. The power-supply will be 33,000 volts from Peoria as heretofore, but direct-current substations and feeders will be installed.

Comparative Cost of Power Production

IN the contest for business which is being waged between the central station and the isolated plant, the limitations of each scheme of service are very clearly defined.

The central station enters the lists with many striking advantages on its side. In the production of the modest and industrious kilowatt-hour that seeks admission into every power-using property lying within its reach, some of the highest achievements of the industrial world are centered.

The central station's most impressive asset is in the enormous scale on which it does business. All things in the well-designed modern power plant are planned along vast lines. To it comes coal, or other fuel, in 100-ton steel cars, or still more economically, in barges holding many times as much. Carried to the bunkers by mechanical forces, no human muscle is involved in handling it from the time it comes on the property until its residue leaves as ash.

In the boiler-room the same large plan is evident. Although modern development in boiler design has not been so spectacular in the matter of size of the unit as has that of engines and generators, yet real progress has been made and to-day an efficiency in the large boilers of 80 per cent. is being attained in many plants.

The strides in turbo-generator designs have raised the size and economy until 18,000 h.p. at a full load steam consumption of as low as 10 lbs. per horsepower-hour are getting into service.

Under the stimulating suggestions of the electrical engineer the steam-driven prime mover has reached a degree of excellence seemingly unattainable a few years ago.

In his own field the designer of generators has approached to within two points of the ultimate limits of perfection in efficiency. Henceforth his efforts must be confined to cheapening and mechanically improving his product.

In the distribution of power from the modern station the same tendency to largeness of construction is noticeable. Oil switches that will break almost any load, cables whose size is limited only by the difficulties of handling, substations larger than the average central station of 15 years ago are the rule.

And so the mammoth system extends until it comes finally in contact with the object of its existence—the consumer. Up to this point it has done things in its own way, but here for the first time it comes into competition with the isolated plant.

This humble object that stands across the pathway of the giant of the day has had a far different history. Like the Irishman's famous pig it is little but old. Since power-plants were, it was.

Living under the same unassuming roof as the load it is fashioned to serve, it is glad to receive its fuel by means of a horse and wagon in the good old-fashioned way. Crude human strength is generally used to handle it from the coal pit to the furnace, and in the same manner the ashes are carried out.

The small boiler of the isolated plant is a midget in comparison with its central-station congener, but it is generally large enough to do its work. By way of compensation it is far less expensive.

In the engine-room the units are only large enough for their loads, and their steam consumption is from two to five times that of the great central-station unit.

It is only in distribution that the small plant begins to come into its own. The distribution factor is the one great point by whose power it is permitted to overcome the weakness due to its disadvantages.

When all these factors come to be analyzed, sorted out and set up for comparison with one another, their relative effect on the total cost of unit of power is more readily appreciated. With this in mind there has been collected from divers reliable sources the production cost data of a group of six central stations, and a group of six isolated plants operating under approximately the same conditions as to the cost of the raw material for the manufacture of power and of the labor involved.

The following tables, giving data for the year ending in June, 1908, covering the power plants operated by the Worcester Electric Light Company, the Lowell Electric Light Corporation, the Fall River Electric Light Company, the Malden Electric Company, the Cambridge Electric Light Company, and the Lynn Gas & Electric Company, are reproduced by the courtesy of *The Engineering Magazine*:

Table 1 gives the total capacity in horse-power of the engines for each station, the total output in kilowatt-hours, and the amount and cost of fuel burned.

In the next table the various items that go to make up the total cost account are given. The only factors of any importance that are omitted are rentals of real estate and costs of station tools and appliances. Worcester and Lowell were the only ones to have any rental, and they were insignificant.

TABLE 1.

Station.	Horsepower of Engines.	Kilowatt-Hour Output	Coal (bituminous) Burned	Cost per Ton.
Worcester	5,900	5,400,192	7,868	$4.79
Lowell	7,390	9,426,511	14,101	4.75
Fall River	4,433	4,061,284	7,630	4.68
Malden	4,875	4,647,453	5,555 coal	4.49
			1,000 coke and breeze	3.72
Cambridge	6,750	6,043,204	9,377	4.40
Lynn	8,200	8,776,166	13,917	3.60
			3,364 bbls. tar	1.50

TABLE 2.

Station.	Operating Expenses.				Plant Repairs.			
	Fuel Cost.	Station Wages.	Water	Oil and Waste.	Station.	Steam.	Electric.	Total Cost.
Worcester	$37,970.06	$19,429.59	$1,843.79	$1,477.31	$650.80	$2,945.15	$2,949.49	$67,441.19
Lowell	67,032.97	24,742.81	730.04	846.04	1,881.90	1,859.69	885.54	100,071.37
Fall River	35,707.29	21,844.77	465.12	1,302.16	466.14	1,491.73	1,168.46	65,075.29
Malden	29,479.72	15,817.19	1,492.24	780.55	1,640.23	3 325.22	653.24	54,652.53
Cambridge	41,546.43	20,920.49	3,281.28	1,118.05	1,241.30	3,557.91	2,761.12	74,426.58
Lynn	54,158.32	25,937.79	3,551.79	1,030.83	4,547.00	12,932.54	3,993.03	103,374.03

Lowell, Fall River, Malden and Cambridge had items for station tools and appliances varying from $2,600 to $300 in round numbers.

In this table the relative weight of the different factors is evident. Fuel is always the most important item and wages next. Steam equipment repairs are, as a rule, less than electric, and much of the repair work in these cases is really maintenance, and is a very variable factor.

For greater conveniences table 3, showing how all the above items enter into the operating cost of a kilowatt-hour, has been prepared.

TABLE 3.—OPERATING AND MAINTENANCE COST IN CENTS PER KILOWATT-HOUR.

	Worcester	Lowell	Fall River	Malden	Cambridge	Lynn
Fuel	.703	.710	.880	.635	.690	.618
Oil and waste	.027	.009	.032	.017	.019	.012
Water	.034	.008	.012	.032	.055	.040
Wages	.360	.262	.538	.342	.347	.296
Station repairs	.012	.020	.012	.035	.021	.052
Steam repairs	.055	.020	.037	.072	.059	.147
Elec. repairs	.055	.009	.029	.014	.046	.045
Miscellaneous	.000	.022	.080	.033	.000	.000
Total	1.246	1.060	1.620	1.180	1.237	1.210

We now have the operating and maintenance cost of the unit of output at the switchboard, and can compare it with the same element in the case of the isolated. It will be borne in mind, however, that as yet nothing has appeared regarding the costs of distribution, which is the great handicap on the central stations.

Turning now to the isolated plant, which for convenience we will designate by their use, we find the following:

TABLE 4.

Plant.	Horse power of Engine.	Kilowatt-hour Output.	Coal Burned.	*Cost of coal per ton.
Bank building	1,500	1,546,000	14,956	3.68
Hotel	250	115,900	1,826	3.72
Store	350	287,100	2,295	3.93
Apartment house	300	232,960	1,920	3.82
Club	225	93,800	1,466	3.44
Factory	1,500	2,125,600	17,251	4.12

*Include cost of ash removal.

In table 5 are shown the operating and maintenance charges for the plants composing the group. It is to be noted that the latter set of items is much lower than those for the central station shown in table 2, the station repairs being included in and divided between the steam and electric repairs.

In comparing these data with the corresponding figures for the central station, one of the things not at first expected is the fact that the fuel costs are lower. This is probably the effect of a better load factor in these partic-

TABLE 5.

Plant.	Fuel Cost.	Plant Wages.	Water.	Oil and Waste.	Steam Repairs.	Electric Repairs.	Total Cost.
Bank building	$55,100	$24,220	$3,535	$1,546	$3,610	$2,016	$90,027
Hotel	6,812	3,690	486	339	554	329	12,210
Store	9,035	4,275	361	221	419	227	14,538
Apartment house	7,340	3,840	303	240	310	218	12,251
Club	5,041	2,710	117	166	212	161	8,407
Factory	71,120	25,160	6,416	624	3.260	2,876	109,456

ular isolated plants. The item of wages also runs lower, probably on account of lower administration costs.

TABLE 6.—OPERATING AND MAINTENANCE COST IN CENTS PER KILOWATT-HOUR.

Item	Bank Building	Hotel	Store	Apt. House	Club	Factory
Fuel	.355	.582	.315	.314	.526	.334
Wages	.155	.342	.149	.165	.289	.118
Water	.027	.042	.011	.013	.021	.030
Oil and waste	.01	.029	.008	.010	.017	.027
Steam repair	.023	.038	.015	.013	.026	.014
Elec. repairs	.013	.028	.008	.009	.017	.012
Total	.583	1.061	.506	.524	.896	.545

In comparing the totals, it is notable that whereas all the central stations' costs run over one cent per kilowatt-hour, only one of the power plants does so, and that one is a hotel.

From the comparison it would appear from the foregoing statistics that even at the switchboard the production cost of power of the isolated plant actually compares favorably with that of the central station; when the distribution charges that are to be added to the items are compared, it is easy to predict that the station will be more heavily handicapped. In another article we will try to arrive at an accurate estimate of the average values of those distribution charges in the two cases.

The Alaska-Yukon Exposition

Details of the plans for handling the crowds at the Exposition are now almost complete.

Expending in lump sums $910,000 for new cars, $600,000 for new trackage and $275,000 for motor generators, transformers, high-power transmission wire and lighting wires and fixtures, the Seattle Electric Co., which controls the local street car and lighting, will make a handsome record in handling the traffic and lighting of the forthcoming Alaska-Yukon-Pacific Exposition. The improvements, new lines and new power facilities which the company is installing preparatory to the 1909 Fair mark a new era in street railway improvement in the Northwest, and at the close of the Exposition, Seattle will be equipped with the most efficient service in the history of the city. For years the electric company has been kept at its wits end in maintaining schedules with its lines constantly impeded by street changes and improvements, not to mention increasing its service to meet the demands of a growing population. The present expenditures will leave the car system in excellent shape after the exposition, and will ensure a prompt and comfortable handling of the crowds at the Fair.

Four lines will tap the fair grounds, two of which are now operating, with one more completed and the fourth just begun. Each line is five or six miles in length. All will be double-tracked with loop terminals at the grounds, and a handsome terminal building and power substation will be installed on the fair grounds. The company expects to be able to deliver passengers at the fair grounds at the rate of two or three cars a minute in rush hours and on special days. As each car comfortably carries 100 passengers, the street railway system will be able to handle twelve or fifteen thousand persons an hour should the occasion demand.

The additional power necessary for these lines will be furnished by the great water-power plant at Electron, on the Puyallup River, and the steam plant at Georgetown. Twenty miles of 13,000-volt transmission wire will connect this power with the substation on the grounds, where it will be stepped down to 2300 volts. Two 1000-kw. motor generators will be located at this station, and two others at substations in the city. The power will be sufficient to handle cars as rapidly as they can be safely moved over the four lines.

The lump order of 140 cars, forty of which have already been delivered, is probably without precedent among western street car systems. The cars are of the most modern type, and cost when set up at Seattle about $6,500 each. They are manufactured by the St. Louis Car Co., and known as single-end, side-entrance cars. Each car has four motors of 37½ h.p., or 150 h.p. in all, and is capable of developing a speed of 30 miles an hour.

Stone and Webster, who control the local company, are not making the investment of one and three-quarter millions of dollars with the expectation that it will all come back in

Continued on page 68

Notes on Switchboard Instruments

H. W. RICHARDSON

COMPLETENESS of detail in modern electric lighting and power stations is essential, and such completeness involves the use of proper switchboard instruments, for upon these depends the safety and efficiency of the entire generating and transmission system, as well as satisfied customers. The instruments must be of the best quality, and their design such that their accuracy may be depended upon for long periods of continued use.

The manager of any manufacturing industry knows the amount of product being turned out, its cost per unit, the number of units sold and how much material is wasted. This is equally applicable to the generation and sale of electricity by central stations. The instruments on the switchboards are depended upon to tell all this, and to show if the cost of production and selling price are reasonable.

The shrewd central-station superintendent desires to render service as satisfactory as others, and, at the same time, increase the dividends to the stockholders. In order to accomplish this with a minimum investment of capital he must know if his own plant is performing its functions as efficiently and economically as possible. He can only know this when he has specific knowledge of the actual working of his station. Without the switchboard instruments this information would be an impossibility.

It was only a few years ago that central-station managements based their selection of switchboard instruments, first, upon the initial cost, and second, upon the accuracy. They now realize that there are many other important features which must be considered. If the instruments are to operate on alternating or direct-current various requirements enter into their construction. Variation of inductive load, wave form, voltage frequency, temperature, etc., all have to be considered.

Instruments, like watches, should receive periodic care and attention. Inaccuracy or gradual deterioration of the instrument is sure to introduce an error, which will result in decreased efficiency and lessen the life of the operating apparatus with consequent increase in expenditures.

It is sometimes said that instrument inspection is unnecessary, for there is seldom anything to correct. It should be remembered that many of the troubles developing after the installation of apparatus begin on an insignificant scale. Once having started, the trouble rapidly increases in magnitude. The small expenditure for inspection is necessary for good service, and will render the necessity for serious repairs an unusual thing. The expense, delay and inconvenience caused by having to remove an instrument from the switchboard and send it to the maker is more than compensated for by keeping a watchful eye ready to detect the slightest fault.

The larger plants, also stations operated by syndicates, maintain elaborate testing departments, with one or more experts who are occupied systematically in locating faults and maintaining everything in good condition. Many stations of smaller size employ one of the regular employes to do the necessary testing.

The data collected by such testing discloses that one of the most frequent sources of trouble and loss to a station is poor voltage regulation. This may be caused by speed variation, overloading, or poor design of the circuits, improper compounding of the generators, inattention to the voltmeter, or some fault with the switchboard instruments. Although poor voltage regulation may be due to any of these troubles, it is very essential to know if it lies in the switchboard instruments.

Close voltage regulation has not been properly appreciated by many plants. The life of incandescent lamps is greatly shortened by increase of voltage; for example, running them four per cent. above their rated voltage reduces their life one half. High voltage causes the lamp user to expect 20 to 30 c-p. from a 16 c-p. lamp, so that dissatisfaction is sure to follow correction of the voltage. Low voltage means poor lights, and hence people will prefer to use gas or oil lights. Voltmeters with continued service are apt to read low rather than high, so that the station attendant will be running the station at an excessive voltage when he believes the pressure normal.

Poor service means dissatisfied customers and retards the growth of business. The writer calls to mind where a supply man reported that his lamps failed to give satisfaction at a certain town. A visit to the plant showed that the attendant employed no voltmeter and informed the supply man that he could detect with his eye when the lamps were at the correct voltage. The lamps in this case were for a 104-volt circuit and were found to be operating at 11½% in excess of this rating. Another station made tests in their potential and found that the secondary voltage varied from 112 to 140 volts, when the normal voltage should have been 110. The effect on lamps, transformer core loss and cost of renewals in either of these two cases needs no comment.

While this evidences the value of a thorough knowledge of operating conditions it also shows the necessity of an accurate voltmeter. Voltmeters are of such vital importance that their initial accuracy as they leave the manufacturers should be within one per cent.

The ammeter, although of great importance, is second to the voltmeter. On constant current series incandescent and arc lighting circuits, or in electro-plating, it is of greater value than the voltmeter. The ammeter shows at any instant the current output of the generator, feeder, or transformer, also when part of the load should be transferred to another generator or station. It serves as an indicator to protect the lines, generators, transformers and other apparatus from heavy overloading, and possible burn out, with attending fire risk.

Indicating wattmeters are not used in direct-current work to the extent they are in alternating-current service. In the latter they are very essential. On polyphase circuits a polyphase indicating wattmeter, showing at any instant the watt or kilowatt output for the circuit to which it is connected, is indispensable.

Indicating wattmeters, when used on the panels for alternating-current generators, serve as a ready means of determining if the field excitation of the machine is giving the highest obtainable power factor. The power factor is a maximum when the excitation is so adjusted that the armature current is a minimum for a given output.

The fact that the polyphase wattmeter indicates on a single scale the total energy of a polyphase system for balanced or unbalanced loads, and this regardless of whether the load

comprises incandescent lamps, arc lamps, fan motors, induction motors, rotary converters, etc., appeals to all central-station superintendents who are the users of polyphase apparatus.

When used on a polyphase circuit, the voltage of which is balanced, a single-phase wattmeter may have its potential circuit so wired to a double-throw switch that it is possible to read the wattless component as well as the energy component.

The ratio of these two quantities is a factor proportional to the available power of the circuit.

Rather than install a double-throw switch and single-phase wattmeter and then compute the power-factor, the power-factor indicator is preferable. While it is necessary to know the efficiency of operation at all time, it is equally necessary to know the phase relations existing in the circuit at any instant. The power-factor indicator serves as a means of detecting cross currents between generators operating in multiple, also if the rotary converters are doing their best work. Since the power-factor of a rotary converter, as well as a synchronous motor, can be varied by altering the field excitation, the alternating-current ammeters may be omitted from the panel and a power-factor indicator substituted.

Not only is it necessary to maintain constant voltage but there is, in alternating-current work, another troublesome factor. The frequency must be maintained at a certain definite value. The importance of a frequency indicator on the switchboard is too often under-estimated. Frequency variation not only effects the efficiency of the generating apparatus and transformers designed to operate at a definite frequency but also may affect, to a degree, the accuracy of the integrating meters upon which the revenue of the station depends. Variation of frequency between prime movers may in turn produce disturbances in other synchronous apparatus operating in multiple. Frequency variation may be due to irregular speed of the engine or water-wheel, as may be the case with a slow-speed reciprocating engine or a sluggish governor, producing in turn cross currents between generators or surging currents developed by synchronous apparatus. Such a variation often causes a flickering of the lights which is unpleasant and tiring to the eye. For such conditions the frequency indicator is invaluable. Not only will it show that this condition exists but it will prove of material assistance in locating the trouble.

While these various instruments serve to indicate the conditions existing at any particular instant, they fail to leave any record. Completeness of detail requires a record of the fluctuation of the voltage, current, load, power factor and frequency in order that necessary steps can be taken to locate and correct these faults. The curve drawing instruments serve this field of usefulness, and at the same time render additional service since they record fluctuations which would doubtless be entirely unnoticed or overlooked with the ordinary indicating instrument.

With the development of the many rate systems of charging for electric energy, the curve drawing instrument is entering a particularly important field. The rate of charge may be based upon the maximum one-minute load or maximum five-minute load or other slight modifications, depending upon the local existing conditions. The record left, therefore, serves as a basis of charge.

There are certain fundamental features which are important in selecting an instrument. It should be direct-reading and accurate all times. It should be simple and neat, rather than complex and composed of many parts. It should be strong and of robust construction, able to withstand transportation and moderately rough usage. When installed on the switchboard, more or less jar and vibration is present. This is apt to affect the accuracy by increasing friction or throwing the parts out of balance. The instrument should be unaffected by the continued jar to which it will be subjected when mounted in place.

The great difficulty in securing accuracy is the smallness of the forces dealt with. The greater the torque, for a given weight of moving element, the smaller the friction error. To increase the torque—other things remaining equal—means increased energy consumption. Increased energy consumption is usually attended with increased electrical errors. The torque must then be as high as possible and yet consistent with low energy consumption, small electrical error, and light weight of moving element.

Friction is present and cannot be totally eliminated. It, however, can be reduced to a minimum. Friction is not a constant quantity but increases as the instrument continues in use. Almost any instrument can be produced with small initial friction, but much thought, experimenting and expense have been directed to secure the best construction of moving parts so that friction would always remain a minimum. High torque is of paramount importance, for if the ratio of torque to friction is high, friction may increase several hundred per cent. without perceptably affecting the accuracy. Many switchboard instruments are now designed so skilfully that the friction error is much less than 3%.

To still further minimize the effect of initial friction, the moving element should be made as light as is consistent with strength, high torque and stability. A light-weight moving element tends to simplify the bearing construction.

Jewel bearings have come to be almost the universal form since they ensure minimum friction and long life. The delicate construction of the bearings means that the instruments must at all times receive careful and intelligent handling. Should the instrument be set down carelessly with considerable jar, the jewels may be cracked, for they are very brittle. This causes increased friction, inaccurate indications and "stickiness." Delicate construction must not be considered a defect for it is necessary. The extreme accuracy demanded of the instrument can only be secured by delicate construction of the various parts.

In order that a violent fluttering or fluctuation of the indicating needle on a rapidly changing current may be prevented, the instrument should possess excellent dead-beat qualities. The permanent and electro-magnetic form of damping are usually the simplest and most efficient.

The finish should receive due attention. It should not crack or peel off but be of a durable nature. The finish should be selected so that it will harmonize with the rest of the switchboard. A dull black finish seems to meet the demands of instrument users. It also has the advantage that if for any reason it should become scratched, a brush moistened with the finish and applied will remove all trace of the sear.

The larger central stations prefer their instruments so constructed that the cover may be easily removed and the internal parts easily accessible for any repairs or calibration. This is important since it may save removing the instrument from the panel and shipping it to the manufacturer for repairs with all the attendant delays and inconvenience, to say nothing of the unnecessary expense incurred.

Switchboard instruments should be unaffected by external temperature variations or internal heating effects. The error should not exceed 1%. This result is not always attained. The writer recalls a test made at 110 volts on a 150-volt voltmeter. The heating effect of the current flowing in the instrument's windings resulting in an indication 7% low. The manufacturer claimed this voltmeter to be "the most perfect on the market."

Instruments are divided according

to their principle of operation into five different types: hot wire, electrostatic, D'Arsonval, dynamometer and electromagnetic, the latter including the induction type.

HOT WIRE INSTRUMENTS

Hot wire instruments are limited in their commercial application to ammeters and volt meters. As their name implies, their action depends on the heating effect produced by the passage of an electric current through a fine wire, causing it to expand. The indications of the needle are secured by the amplification of the motion of this expansion or lengthening of the wire. A spring keeps the moving system always in tension, and furnishes the necessary torque for moving the indicating needle up the scale.

It will be observed that the action of the spring of the hot wire instrument is the reverse of that of any ordinary type, for in the latter the spring tends to bring the needle back to zero.

Figure 1 shows a hot-wire gauge instrument, in this case an ammeter, operating from a shunt. In this instance the wire which is heated is held in the rectangular frame, and zero can be regulated by the regulating screw R. T1 and T2 are the main circuit terminals. P is the pulley which also supports the pointer of the instrument, and S is the spring which is controlled by the expansion or contracting of the wire. The conductor F, in this particular type of instrument, is of some very flexible material, such as silver foil, and does not in any way interfere with the free movement of the wire.

When the current flows through the main circuit, in this case from T1 to T2, the direction of the passage through the shunt and hot wire is indicated by the arrows.

Since hot wire instruments operate without magnetic or electrostatic influences, they are free from errors due to frequency or wave form variation. They can be calibrated on direct current and used with equal accuracy on alternating current or vice versa. They are uninfluenced by stray electromagnetic or electrostatic fields, or hysteresis, and are dead beat. This type of instrument has, however, one inherent defect and that is the tendency to creep or lag. To illustrate, 125 volts is thrown on a hot-wire voltmeter whose full scale reads 180; the needle quickly indicates 115 volts, but it is necessary to wait five or six seconds before it reaches the 125 mark. The instrument is, however, very sensitive to even small fluctuations of the current, fluctuations as low as two-tenths of one per cent. of full scale can be easily detected. When the current is taken off the instrument the needle returns immediately to within one-eighth to one-sixteenth of an inch of the zero mark, and then occupies at least one to two minutes to creep back to zero. If the instrument is in good

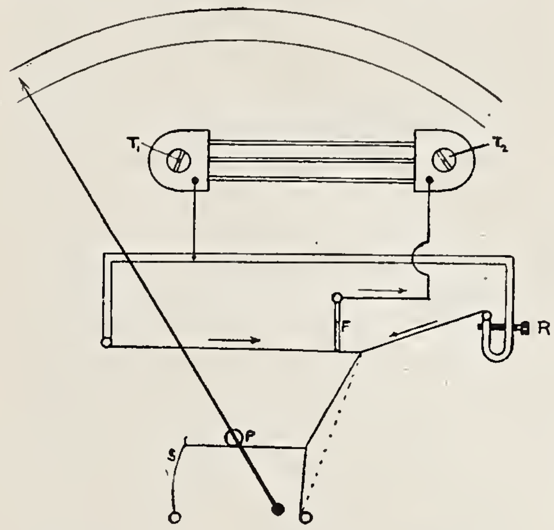


Fig. 1.—HOT-WIRE SHUNT AMMETER

condition the needle will usually return to zero if given sufficient time. If, for any reason, the needle should permanently change its zero position, an adjustment is provided for regulating either the slack of the wire or the tension of the spring.

Platinum silver wire is used for the expanding wire because it can withstand considerable heating without taking a permanent set or oxidizing, and moreover possesses a low temperature coefficient. The expansions dealt with are very minute, being between .003″ and .01″, hence if the spring is too strong the wire is apt to be stretched. This limitation of the spring's strength also limits the torque.

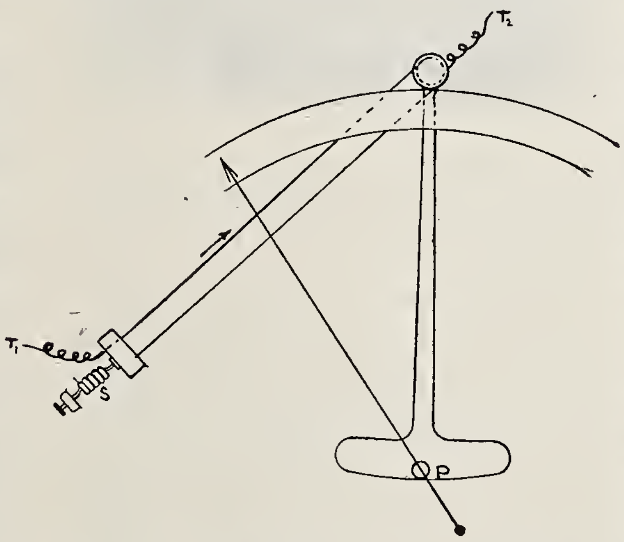


Fig. 2.—SELF-CORRECTING HOT-WIRE METER

In order to exclude the effects of external temperature variation, different devices have been resorted to such as supporting the expanding wire from terminals which are mounted on a base having the same temperature coefficient as the wire. The wire being very small (.15 to .25 mm.), takes up any change of temperature rapidly as compared with the comparatively massive base, and lag of the indicating needle results. The wire must necessarily be small to avoid sluggishness. To secure maximum expansion the wire must be worked as hot as possible; hence it may burn out on heavy overload. The mass of the expanding metal is so small that it may on a heavy current increase its temperature more rapidly than a fuse. The manufacturer of one type of hot wire instruments employs a unique and highly commendable scheme to compensate for temperature variations. This is shown in Figure 2. The expanding wire is looped about a small pulley, both ends of the wire being secured to a support which is held by the control springs. Current applied at terminals T1, T2, is carried by only one-half of this wire, thus causing a slight turning of the pulley (P). The movement of the pulley is transmitted by suitable multiplying devices to the indicating needle. When the temperature of the air changes both wires are affected alike, hence there will be no movement of the pulley and the position of the needle will be unaffected.

Since the indication of hot-wire instruments depends upon the heat developed in the expanding wire, and the heating effect is proportional to the square of the current, it is obvious that the normal scale follows a square law. This means that near zero the scale will start with small divisions, gradually increasing in width. This is an advantage for voltmeters, since the scale is open at the normal operating portion, but it is a disadvantage for ammeters.

Hot wire voltmeters are made on the same principle as the ammeter shown above, except that no shunt is used, and there is very little difference between the mechanical construction of the two instruments. The differences lie in the wire itself, and in the method of connecting. The wire of the voltmeter is on a finer gauge than that of the ammeter, and is usually connected in series with a resistance.

Ammeters are not usually built above three amperes for direct connection into the circuit; they are almost universally operated from shunts. This introduces the disadvantage of large power consumption, contact troubles and shunt temperature errors. When operated on alternating current, it is advisable to use series transformers and eliminate the source of these unfavorable features. The voltage drop on ammeters at full load approximates .2 to .25 volts, while the voltmeter requires a current of .15 to .25 ampere. A 3000-ampere ammeter operated from a shunt then requires 750 watts, or one h.p. to operate it at full load, while a 750-volt voltmeter with .2 ampere takes 150 watts, or one-fifth h.p.

A damping attachment consisting of an aluminum disk fixed to a pivot and moving between the poles of a small, permanent magnet is often provided both with voltmeters and ammeters. The object of the damper is rather to minimize the effect of external vibration than to render the instrument dead beat, as they inherently possess this quality.

The hot-wire instruments now on the market are fairly accurate and can be used with gratifying results in the presence of strong stray fields, or on direct or alternating-current provided rapid reading are not required. The hot-wire instrument is the only commercial switchboard instrument which is available for high frequency work.

The Workshop and the Schools

Edwin Reynolds, the late chief engineer of the Allis-Chalmers Company, who died at his home in Milwaukee on February 19, aged seventy-eight years, was a most admirable example of the great engineer evolved from the workshop. Mr. Reynolds was born in Mansfield, Conn., on March 23, 1831, and all the schooling he had was received in the public school of his native village. He served an apprenticeship with a small machinist in that town, and, equipped with his "trade," went to work in machine shops in Connecticut, Massachusetts, Ohio and Indiana, and rose by merit to be foreman for Stradman & Co., builders of engines, saw mills and drainage pumps at Aurora. Later, returning to the East, he entered into the employ of the Corliss Steam Engine Company, at Providence, R. I., where, under the personal guidance of Mr. Corliss, he rose to be superintendent in 1871. It was here that he began to show ability as an engineer. It was he who designed and built the great "Centennial" engine, exhibited at Philadelphia in 1876, and it was to be his privilege during the next twenty-eight years to see the products of his skill successively shown as "Big Engines" at Chicago in 1894 and at St. Louis in 1904.

The two later engines were designed and built by Mr. Reynolds for the E. P. Allis Company, and its successor, the Allis-Chalmers Company, as Mr. Reynolds had joined E. P. Allis in 1877.

Mr. Reynolds' reputation as an engineer was built upon notable achievements. He originated the Reynolds-Corliss valve gear, which is the foundation of all the Corliss valve gears in use; he originated the type of blowing engines used in all iron furnaces; he made the steam stamp used in the Lake Superior copper regions; the modern pumping engine was his conception, and finally he conceived and built the Manhattan type of engine, which creates the vast electric power for our elevated and subway railroads.

There was no doubt of his high standing as an engineer, and, moreover, he was always at the same time a mechanic. He designed nothing that could not be built and nothing that could not be built with the facilities which he knew were available.

His last great feat was the designing and building of the west Allis works of the Allis-Chalmers Company. This, perhaps, is one of the most notable of his feats. The works is not only the most perfect, perhaps, of all the great engineering works of the world, but they have the unique distinction of having been entirely designed along ideal lines before even a site was chosen, and then the site was selected for equally ideal reasons.

The engineering success of a man like Mr. Reynolds is apt to bring to the front the old query: "If a man

can become the leader of his profession with only a shop training, what is the use of a university or technical school education?"

The answer is not really hard to find. There are men holding high places in some of our great electric concerns who have risen to eminence with no better foundations than Mr. Reynolds had. Their success, like that of Mr. Reynolds, was due to their ability, but their opportunities came largely from the existence of a peculiar condition in their industries, which prevented their lack of schooling from handicapping them.

"We were pioneers in our field," said one of the high officials of the General Electric Company recently, in explaining his success, "and nobody knew any more than we did."

Mr. Reynolds was a pioneer in his field. There was little of value that the schools could have taught him that he did not learn as well in the shops. There may be fields of engineering where the like is true to-day, but we do not recognize them. In the generation that has seen the career of Mr. Reynolds and his compeers there has grown about their work such a mass of scientific knowledge and data that the youth who would assay success to-day without a technical schooling is braving fate. He may succeed in catching up with and even passing the college-bred man, but his chances do not equal the risk of failure. The schools can in a few years put him abreast of where Mr. Reynolds lay down the burden of his work, while a generation in the shops would leave him struggling in the rear. All hail to the great men of the Reynolds type, but this is the day of the college man.

The Alaska-Yukon Exposition

Continued from page 64

nickels during the period of the exposition. To accomplish such a result the street cars would have to handle something like 35,000,000 people during the four months and a half that the fair will last, which is obviously out of the question. If a quarter as many people attend, the 1909 Exposition will be a record breaker. The present improvements of the car system are all in the nature of permanent investments.

For the lighting of the exposition the same company has the contract, and is preparing a most elaborate illumination.

The substation on the fair grounds will be the source of current, and all wires will be laid in underground conduits, thus eliminating the unsightliness of poles or wires on the fair grounds.

The lighting power will come from the same sources as the transportation power. At the substation will be four 1000-kw. transformers with the necessary regulators and switches. The outdoor or decorative lighting currents will pass through a rheostat, the plan being to turn on the lights all over the grounds gradually, starting with a mere twinkle and growing slowly into brilliant illumination. The water front on Lake Washington and the terraced hillsides overlooking the lake, with the wide avenues of the exposition leading down to the shore, will be brightly lighted, and the night scene from the water promises to be marvelously effective and inspiring.

The Weber Gas Engine Company, of Kansas City, has passed into a receivership instituted by a friendly suit. The intent of this is to permit a reorganizaton of the company whereby it may be placed on a stronger financial basis. The company reports business good and its shops are running full time. It will continue to enter and carry out contracts as heretofore and hopes soon to be on a better footing than ever.

Why the Meter Read High?

In both the gas and electric fields a never-ending cause of argument has been the question of recording meters not reading correctly. The following is the true account of one man's experience with a meter which was found to have this bad habit.

A and B were friends who worked at adjoining desks in the office of a large corporation located downtown in New York. One day the literature of a real estate agent, who was opening up a new tract of land in New Jersey, fell into B's hands. He approached his friend about buying a home and, as a result, in time, they selected houses adjoining each other on this tract.

After some months, when A was visiting B one evening, the question of charges for electric power came up and A asked:

"Charlie (B), what does your electric light bill run per month?"

"The bill I received this morning was for $4.25," was the reply.

"Four twenty-five? Aren't you mistaken, Charlie? Our houses are alike and yet my last bill was for $6.30."

"Oh, no, Will, it has been running at about that amount for some time."

"Then my meter must be wrong," said Will. "I guess I'll report it for inspection to the company."

On his way down to catch the New York train next morning, he stopped in the office of the electric company and explained his trouble and asked to have an inspection made.

Later in the day an inspector took up the case and, as a preliminary, took note of the office records. Each house showed 25 outlets of which 15 were equipped with 16-c-p. lamps and the balance with eight candle-power globes. In addition, each patron had one 12-in. fan.

On arriving at A's the inspector first tested the meter and found it O. K. to well within the legal error. Then he went up into the house and checked up what was supposed to be the right number of lamps and fan, and found everything agreeing with the office record. He then visited the adjoining house owned by B and here he duplicated the tests made at the first house. Here likewise the meter was found legally correct with all other apparatus checking with the record.

The next day a report was sent to A telling him of the inspection of his house, showing that his meter was in first-class working order, that the wiring system was free from grounds or other troubles, and that his whole installation was in fine shape. Mr. A thanked the company for its prompt and thorough attention to his complaint.

When bills for the next month's account had been sent to consumers, A again enquired of B about the amount of his bill, and again found his amount about 50 per cent. higher than B's. Again he reported this question of excessive charges to the company and a second test again showed nothing out of order in any way. The company assured Mr. A that he was only being charged with the amount of current he was using, but confessed itself unable to account for the difference.

The morning after the bills for the next succeeding month had been rendered, A tore into the light company's office and demanded of the office boy to be shown to the manager at once. Anger and indignation marked his every movement. As soon as he caught sight of the manager he broke out with:

"Here, you scoundrel, get your wires and power out of my house just as quickly as you can. I won't be swindled by a lot of thieves any more. Get them out, do you hear? get them out. I'll give you until noon to do it, but I want them out as much sooner as you can get your men up there. I'll use candles before I submit to such robbery any more!"

When the manager had quieted him enough to find out the cause of the outburst, he discovered a very interesting situation. When A had received the second report of O. K. from the light company he had gone to his friend.

"Say, B, I have just received another report from the electric company stating that my meter and lights are all right. Now I want you to give me some help in running this down. Your house is exactly like mine. You have the same electric equipment as I have and your family consists of yourself, wife, baby and nurse, the same as mine. Will you try to close up your house each night for this month at the same time as I do, and see how we come out? Of course, our bills won't be exactly alike, but close enough to check."

"Why, of course, Will," his friend replied, and they started that very day, the second of the month.

At the end of the month the bills were awaited with eagerness. When they came A's called for the payment of $6.50, and B's $4.10. Both men agreed that A was being swindled. The call at the manager's office next morning resulted.

The manager did his best to try and persuade A to retain his electric connection, but that individual was too mad to listen to such suggestions.

During the day the manager made a trip up to A's home with the man assigned to disconnect. For his own satisfaction another series of tests duplicating all previous ones was made, with the result of showing everything O. K. Then he went up into the house and opened up a conversation with the nurse about the habits of the household, endeavoring to learn in this way what might account for extra current consumption, but no gleam of light could be deducted from it. While talking with her, Mrs. A came in and enquired what his business was, and on learning it confirmed within the next few minutes the statements made by the nurse.

The managed was about to leave with no solution apparent, when his ear caught a buzzing sound.

"What is that?" he asked.

"Oh, only the fan putting the baby to sleep," Mrs. A informed him.

"Fan, putting the baby to sleep?" he enquired; "I don't believe I just grasp what you mean."

"Oh, we put the fan in the upturned box cover of the sewing machine and let it blow so that it just creates the slightest breeze over the baby as he lies asleep," vouched Mrs. A. "The baby has grown so accustomed to it we let it blow all the time he is asleep, otherwise he will awaken and cry."

"How long does he usually sleep, Mrs. A?" the manager asked.

"Oh, nearly all the afternoon," was her answer.

The manager thanked her and departed. At the office it did not take long to figure out the cost of fan-motor current to check within a few cents of the unaccounted extra charges.

That night he sought Mr. A in his home and reported a new test by himself with different results than before.

"You are paying about four dollars a month for lighting current, the same as B, but an extra charge of about two dollars to put the baby to sleep."

"Two dollars to put the baby to sleep? What do you mean?" asked A.

The manager explained the point and A called upstairs to his wife:

"Say, mother, do you use the fan on the baby every afternoon?"

"Yes, Will," she answered, "nearly all of every afternoon, for he won't sleep without it."

A looked at the manager for a second and then broke into a laugh.

"Well, I'll be d—d," he commented. "Take this bill and blow the boys in the office to cigars and tell them it's on me this time."

M. O. Buckley.

Operating Performance of Some Isolated Plants

A study of the actual, every-day results from the operation of well-designed, modern, gas-driven, isolated plants leads one irresistibly to the conclusion that to this type of prime mover belongs the future of the isolated plant in cases where the heating problem does not enter. As an example of what can be done, we have recently received information concerning a plant in the city of Grand Rapids, Michigan, which by the way has a very low public rate, two cents per kilowatt-hour being a not unusual quotation to owners of even small-sized plants. Therefore we believe it will be of particular interest to mention the case of a gas power-plant installed by the Olds Gas Power Company for the Heyman Company of that place.

The Heyman Company conducts a household furnishing department store, and, until a large extension to their building was made, maintained a small gas-engine plant, which was not operated but just kept there to secure a reduction in the electric current rate. As the company furnishing the current was not inclined to extend the low rate on the new building, the management decided to purchase an independent plant. To avoid any waste in floor space, this plant was installed under a 17-ft. wide loading platform, and consisted of two 65-h.p. Olds gas engines belted to a dynamo, and a 130 h.p. Pintsch suction gas producer.

The reason for installing one producer with two engines was lack of floor space, and the desire to reduce the amount of attendance required to the minimum. That this latter requirement was fully met is best proven by the fact that no extra attendant was engaged to take care of the plant, the engineer who attended to the electric wiring, elevators, heat, etc., around the premises also attending to the producer installation; and this notwithstanding that the plant for the first two years after its installation was maintaining a twenty-four-hour service from Sunday night until Sunday morning.

The load conditions of this plant are such that during the major part of the forenoon it does not exceed, at the most, 10 h.p., and one of the engines is in service at that time. The conditions of the load remain the same, with slight variation, until some time in the afternoon, when the load rapidly comes up to full capacity of one engine, but seldom exceeds it. But by the time the display signs are thrown in, the load is up to full capacity, and often in excess of the rated power of both engines combined.

The load so remains until the closing hour, after which part is removed, but even then the current consumed by the lamps, display windows and signs is in excess of the capacity of one engine, so that two units are in operation until eleven o'clock. Formerly one of the engines was kept running throughout the night. This was primarily to save the engineer the trouble of starting up in the morning. Now the plant is shut down, as stated above, and started at six o'clock in the morning. It is interesting to note that the plant in question, from about six o'clock in the evening until the time of shutting down, as given above, is operated practically without an attendant, the engineer leaving the premises, and the only attention given to the plant is that each hour, in making his rounds, the watchman stops into the engine-room. Being an elderly man with no particular disposition to interfere with anything mechanical, he limits his efforts strictly to the few manipulations required when the apparatus is taken care of for the night, viz., at eleven o'clock.

It will be seen from the above that the load factor in this installation is not a favorable one for high economy. Notwithstanding this, when some time ago the Muskegon Heat, Light & Power Company proposed to furnish current to the firm at 1½c. rate per horse-power hour, without any restriction as to minimum rate, meter charges, etc., after a careful anaylsis and observations as to the current consumed and the cost of current generated in the plant installation, lasting from four to six weeks, it was found that, including all charges except the charge for the attendant, whose services were required in the building of this size previously and irrespective of whether or not the plant were in use, the current cost was 1.1 c. per kilowatt hour, delivered at the switchboard. In view of these results, the offer of the Muskegon H. L. & P. Company was not accepted.

Among other advantages gained, it is stated that only since the firm has had its own plant have the employees come to realize the advantages of artificial light. No efforts are made to reduce the number of lights burning, and as a result the store is always lighted to the best advantage of the customers and store employes, and to bring about the most attractive display of goods.

Another case in point is that of the Home Electric Light & Power Company, of Greeley, Colorado. This plant consists of two 150-h.p. suction producers feeding four 75-h.p. gas engines. The fuel used is a mixture of anthracite coal and coke which costs in the neighborhood of $6.00 per ton. Notwithstanding this high fuel cost, the management states that the total cost of output, including operating expenses, interest and depreciation, is 1.65 cents per kilowatt-hour as against a cost of three cents with the old steam plant.

Correspondence with many users of isolated producer gas-driven plants as to the alleged disadvantages of noise, smell, oil splash, dirt, vibration, insurance, increase, value of floor space and all other disabilities charged against the gas engine, has failed to unearth many grievances. In fact the first one only, that is to say, noise, has been seriously considered and it is found that wherever proper provision has been made for its suppression, no inconvenience or complaint has been experienced.

In the plant at Greeley, Colorado, the noise heard by a person standing in the railroad depot is less noticeable than that issuing from a steam plant which is 100 feet further away. As a rule, in most of these small plants the principal noise is that due to the belts.

The best comment on the whole situation is the rapid increase in the number of gas-driven plants that are now under consideration and being installed.

Useful to Exporters

"Aid to Shippers" is the title of a 72-page book containing a quantity of information of value to all engaged in the export or import trade. The book is issued by Oelrichs & Co., of New York, for more than 40 years the American representatives of the North German Lloyd Steamship Company, who by reason of long experience are qualified to advise.

The tables of foreign moneys with United States equivalents, together with weights, measurements, tariffs, customs requirements, etc., etc., will be found of great value.

"Aids to Shippers" will be sent, postpaid, on request to Oelrichs & Co., Forwarding Department, 5 Greenwich St., New York.

Mr. Charles T. Main, Boston, Mass., well known through his extended practice as mill engineer and architect, has been appointed by the Council of the American Society of Mechanical Engineers as a member of the National Conservation Commission, with special reference to water powers. Mr. Main is particularly well equipped for this work through wide experience in examinations and reports upon various water powers in this country and in Mexico and British Columbia. He is just now engaged in two large developments on the upper Missouri River near Great Falls, Montana, each of which will provide for the distribution of 36,000 h.p.

Hydro-Electric Power Plant of the West Point Mfg. Co.

A most important water-power development and one which marks the steady progress of the South in the utilization of her large natural resources is shown in that just completed by the West Point Mfg. Co., at Langdale. Ala. The magnitude of the work is significant in itself of the awakening of the Southern manufacturer to the economic possibilities presented by the abundant water power for the generation of electricity.

Chas. T. Main, Mill Engineer and Architect, of Boston, Mass., designed the station and had in charge the installation of all motors except those in the Shawmut Mill, also transformers and transmission lines of which the following is a description.

Langdale is situated about thirty-five miles above Columbus, Ga., on the Chattahoochee River. At this point the river is nearly 1600 ft. wide. From the reports of the U. S. Geological Survey, the minimum flow recorded is about 800 cubic feet per second. Taking everything into consideration it was decided to develop the privilege for a flow of 3000 cubic feet per second. The normal head is 13 ft., which may be increased by the use of flash boards to 16 ft.

The power-house is built directly on a rock foundation, concrete being the material used up to the level of the main floor. The superstructure is of brick surmounted with a cinder concrete roof supported by steel trusses. This house is 214 ft. long by 35 ft. wide. The switchboard is located in the bay in the centre of the building. All station wiring is encased in lead sheathes and carried in trenches built into the concrete floor.

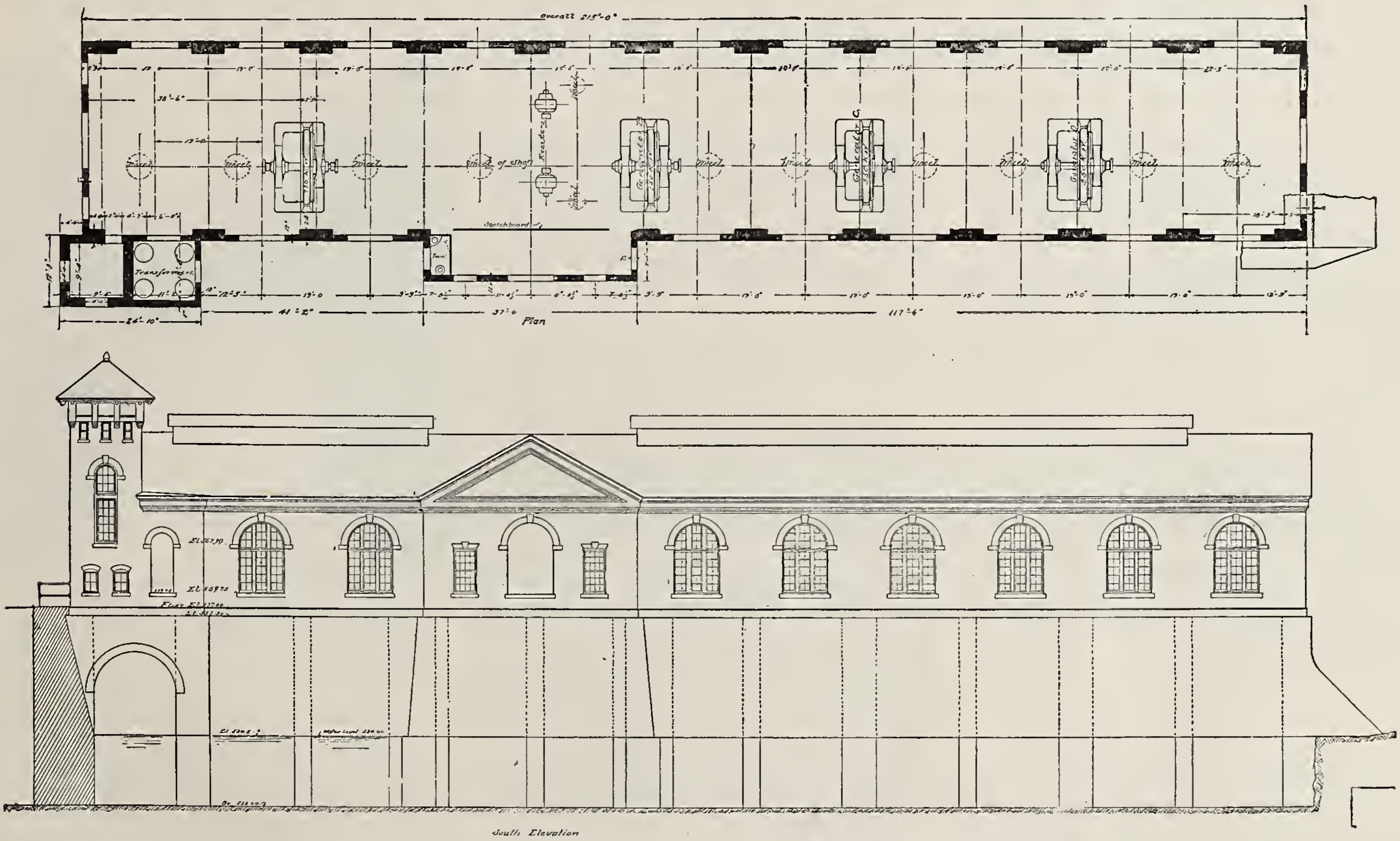
Owing to the low-head conditions it was necessary to adopt the vertical type of turbines and transmit power by means of bevel gears to the generators, which are direct connected to horizontal jack shafts.

The total power is divided into four units, one of 750 kw. and three of 550 kw. capacity each. An engine, previously installed, will drive a 400-kw. belted generator to act as a relay. The 750-kw. unit is driven by four 60-inch "New American" turbines, built by the Dayton Globe Iron Works, Dayton, O. Two of the 550-kw. units are driven by turbines of the same make. The above turbines are of the cylinder gate type, so designed as to have their racks and pinions out of water and accessible for lubrication. The remaining 550-kw. unit is driven by two Samson turbines used in the old development. The total capacity of the water wheels at 13-ft. head (without flash boards) is about 3250 h.p., which will require a flow of a little more than 300 cubic feet per second. Each unit of the new turbine installation is controlled by a Lombard type "N" governor, made by the Lombard Governor Co., of Ashland, Mass.

Excitation is furnished by two 85-kw., 125-volt exciter units driven by Morse silent chains from a jack shaft driven by two 39-in. New American turbines. Woodward governors are here used, made by the Woodward Governor Co., Rockport, Ill. The generators, including exciters and switchboard, were furnished by the Westinghouse Electric & Mfg. Co. These generators are designed to deliver three-phase 60-cycle current at 600 volts, and have sufficient capacity to maintain full-load conditions at 80 per cent. power factor. Their speed is 150 rev. per min. Of the total of 2400 kw., 1400 kw. is to be available for transmission to and use at the new Shawmut Mills, situated two miles distant.

The switchboard upon which are all the controlling switches for the circuits to the Langdale and Shawmut Mills is located near the center of the power-house in the exciter bay. Current for the Shawmut Mills leaves the main switchboard at 600 volts and passes to the transformers in the tower at one end of the building, where it is stepped up to 11,000 volts. At the receiving end it is stepped down again to 600 volts for use with the motors.

There are four 500-kw. transformers at each end of the transmission line, three for regular use and one for a spare. These transformers are con-



PLAN AND ELEVATION OF WEST POINT MFG. CO.'S POWER PLANT

trolled from a selector panel on both high and low-tension sides, so that in case of accident the extra can be quickly cut into the place of any one of the others.

The transmission line is of two B. & S. copper wire spaced 30 in. on centers. At each end is installed a high-tension oil-switch, and in addition to a set of lightning arresters a grounded galvanized cable is carried along the conduit for its entire length as a double protection. The transformers inside the power house and all points of high-tension circuit under cover are installed in separate fireproof rooms.

The lighting at Langdale is secured by transforming down from the generator current at 600 volts to the lighting voltage in the yard. All high-tension switches, lightning arresters, and all mill motors, together with their switches, auto-starters, were furnished by the General Electric Co. The transmission lines and all wiring was furnished and erected by the Carter & Gillespie Electric Co., Atlanta, Ga.

The station floor is located 10 ft. above the crest of the dam, and this is well above the level of the severest floods.

The work has been designed with the maximum high-water conditions in mind, and no expense has been spared to make this station the best equipped of any in the South for the purpose in view.

B. H. Hardaway, of Columbus, Ga., was the contractor for the station foundations and dam construction, and the J. F. Gallivan Building Co., Grenville, S. C., built the superstructure of the station, part of the dam and the small parts of the miscellaneous work incidental to the finishing of the job.

General News

The tungsten lamp patent fraud case has ended with Barton, the dismissed examiner, getting three years in the penitentiary and Everding, the outside accomplice, two years.

A bill has been introduced into the Montana Legislature empowering the corporate authorities of any city in that state to regulate rates and charges for water, gas and electricity to residents.

The Brooklyn Rapid Transit Company, after many years of promise and endeavor, has at last declared a quarterly dividend of one per cent., payable April 1st. The company hopes to continue to pay dividends, but has not definitely committed itself.

The municipal gas and pumping plant of Fairfield, Iowa, has been sold by the city to a private concern at a price considerably below its original cost. It is said that the depreciation on the plant is so great that $50,000 will soon have to be expended in renewals and repairs.

It is said that the Connecticut River Company has completed its plans for a dam between Windsor Locks and Endfield, which will enable it to develop about 10,000 h.p. without interfering with any navigation projects. The power generated will be sold for industrial service throughout the adjacent territory.

The Metropolitan Electric Company, of Reading, Pa., is about to reconstruct its powerhouse, transmission and distribution system in order to meet the increasing demand for a current for light and power purposes. The new plant will cost about $1,750,000, and will be provided for by the issuing of five per cent. thirty-year bonds.

The United States Government is to bring suit against the Truckee River General Electric Company, the California-Nevada Electric Power Company and other parties to acquire possession of a certain tract of land at the outlet of Lake Tahoe, which is necessary to carry out the irrigation plans of the Reclamation Service.

The Mexican Northern Power Company has been organized by a group of Canadian capitalists for the development of hydraulic and irrigating rights in the northern part of Mexico. The company expects to develop 30,000 h.p., and will have a capital stock of $10,000,000 and an authorized bond issue of $7,500,000, of which $5,000,000 have already been subscribed. G. F. Greenwood, until recently general manager of the Havana Electric Co., is president, and W. F. Tye, late chief engineer of the Canadian Pacific Railway, is consulting engineer.

The Electric Storage Battery Company announces that it has recently received a contract from the New York Edison Company for the installation of a battery at the 16th Street substation, which will be the largest central-station battery ever installed. It will consist of 150 cells, and has a capacity of 22,000 amperes for one hour at about 120 volts. It will be used for emergency service, and will be equipped with a set of the Storage Battery Company's economically controlled high-speed and cell switches.

This is the forty-first battery of this make installed by the New York Edison Company, the total capacity of all these batteries now being nearly 193,000 amperes for one hour at 120 volts.

The Supreme Court of Massachusetts has reaffirmed the decision of the lower court, made over a year ago, regarding the New York, New Haven & Hartford Railroad Company's ownership of certain trolley lines in that State. The railroad company must dispose of all of its holdings in these companies before July, 1909. It is understood that this action is based on special circumstances, and the question of its wider application remains open for the present.

The New York, New Haven & Hartford Railroad is now in full possession of its electrical equipment, which was turned over to the company on Feb. 1st. Up to that time the Western Electric Manufacturing Company had kept a small force of men at the Cos Cob shops, which was engaged for the most part in making certain changes and improvements in the 35 electric locomotives that were bought on the original order. This force has now been withdrawn, and the railroad company's employes have full charge.

The General Electric Company and the Siemens-Schuckert Company, of Germany, are to construct a high-speed electrical railway between Cologne and Düsseldorf. According to the plan, as at present outlined, there will be no terminal station, but the trains will run through the streets into the center of each town. Within the city limits the speed of the trains will be kept down to eight miles an hour, but the contractors undertake that the entire distance of 40 miles between the two cities shall be covered in 40 minutes.

At a recent annual meeting of the Western Electric Company it was announced that the earnings of the fiscal year ending Nov. 30, 1908, showed a large decrease as compared with 1907. It was stated, however, that owing to the energetic sales campaign which the company had carried on, some departments of the concern had been kept fairly busy. The total number of orders received in 1908 was about 20 per cent. larger than for the previous year, but the average value of the order was only $47, as against an average value of $98 for the year 1907. The debts of the company have been reduced about $6,000,000 during the year, and on Dec. 1st amounted to about $11,500,000. The cash in hand and bills receivable amounted to $5,000,000 more than the total indebtedness.

Vacuum Testing Apparatus

An ingenious method of testing the degree of vacuum in incandescent lamps has been devised by the Dyer Machine Company, of Lynn, Mass. It is based on the well-known fact that the color of the electrical discharges through a gas in an enclosed vessel is modified by its density, *i.e.*, by the degree of vacuum in the vessel. The discharge is furnished by a high-potential coil, a terminal of which is connected to the lamp to be tested. The general arrangement is shown in the cut. The air or other gas within the bulb becomes luminous and glows with its characteristic color. The results are as follows:

1. A lamp which is completely full of air cannot be made to glow.

2. A lamp containing a considerable amount of air shows purple streamers branching from the filament to the glass, and is probably cracked, and will burn out in an hour or two.

3. A red glow uniformly distributed throughout the bulb indicates a better vacuum than the above. This lamp contains some air and the candle-power will drop very rapidly, probably to 10 c-p. within an hour.

4. A lamp with a white glow with the slightest tint of pink close to the glass is slightly better than the above.

5. A lamp with a whitish glow, but showing the filament very distinctly and with a marked glow about the joints, while containing a better vacuum than the above is still a very poor lamp and will deteriorate very rapidly.

6. A lamp with a white glow uniformly distributed throughout the bulb may burn a hundred or two hours without burning out but the candle-power will drop rapidly.

7. A lamp with a thin, whitish glow more or less intermittent and sometimes hard to start is a lamp which most lamp manufacturers pass as O. K. After such a lamp has burned for about half an hour the glow will usually be found to have disappeared. Such a lamp will drop in candle-power much more rapidly than a lamp with a perfect vacuum.

8. A lamp which shows an intermittent flicker of light on the inside surface of the bulb contains a very good vacuum. Such lamps are universally passed as excellent by lamp manufacturers.

9. A lamp which shows no glow whatever possesses a still higher degree of vacuum than the above, and as this "glow test" is the most severe test known for vacuum it is as high as the lamp manufacturer can obtain and such lamps may be considered perfect.

Selective Radiation of Incandescent Lamps

The February meeting of the New York Section of the Illuminating Engineering Society was held on February 11th in the Engineering Societies Building, the small attendance being in a measure offset by the number of prominent men present.

A paper entitled "Selective Emission of Incandescent Lamps as Determined by New Photometric Methods," by E. P. Hyde, F. E. Cade and G. W. Middlekauff, was read by the first-named, and this abstruse subject was presented in such a manner as to be readily understood by all.

The authors investigated seven kinds of filaments by the method which was first outlined by Holborn in his original description of the Holborn pyrometer, and which was subsequently applied by Drs. Waidner and Burgess in their recent work, "Preliminary Measurements on Temperature and Selective Radiation of Incandescent Lamps," and the result of the investigation are given in Tables 1, 2 and 3.

TABLE I.—AVERAGE VALUES OBTAINED ON LAMPS OF EACH TYPE AT VOLTAGES CORRESPONDING TO A "COLOR MATCH" WITH THE STANDARD LAMP AT 75 VOLTS.

Types of Filament	Red Black Body Temperatures	Relative Per Cent Change Cp. for 1% Change in Watts.	Lumens per Watt.
Untreated carbon...	1420 C.	1.00	1.00
Helion............	1405	1.00	0.97
Treated carbon.....	1395	0.97	1.06
Gem...............	1400	0.98	1.05
Tantalum..........	1340	0.83	1.28
Tungsten..........	1345	0.79	1.49
Osmium...........	1390	0.80	1.85

Thus, from the data given it will be noted that when these various types of filaments have the same distribution of energy in the visible spectrum, the lumens, per watt range from unity to 1.85.

If there were no relative selectivity, the lumens per watt would be unity for every type. There is marked evidence, therefore, that there is considerable selectivity among the different types of filaments, and it is quite interesting to note the order in which the filaments arrange themselves. A higher value of lumens per watt, as, for example, the value of 1.85 for the osmium lamps, as compared with 1.00 for the untreated carbon filaments has the same distribution of energy in the visible spectrum as the untreated carbon filament, the energy curve of the osmium lamp drops off considerably in the infra-red as compared with the energy curve of the untreated carbon. In other words, the osmium radiates selectively in favor of shorter wavelengths, that is, in favor of the visible spectrum, and is, therefore, a more efficient luminous radiator than an untreated carbon filament.

TABLE II.—AVERAGE VALUES OBTAINED ON LAMPS OF EACH TYPE AT VOLTAGES CORRESPONDING TO A "COLOR MATCH" WITH THE STANDARD LAMP AT 100 VOLTS.

Types of Filament	Red Black Body Temperatures	Relative Per Cent Change Cp. for 1% Change in Watts.	Lumens per Watt.
Untreated carbon...	1680 C.	0.86	3.85
Helion............	1650	0.85	3.85
Treated carbon.....	1645	0.84	4.15
Gem...............	1650	0.84	4.0
Tantalum..........	1570	0.72	4.35
Tungsten..........	1555	0.71	5.25
Osmium...........	1610	0.69	5.9

TABLE III.—AVERAGE VALUES OBTAINED ON LAMPS OF EACH TYPE AT VOLTAGES CORRESPONDING TO A "COLOR MATCH" WITH THE STANDARD LAMP AT 125 VOLTS

Types of Filament	Red Black Body Temperatures	Relative Per Cent Change Cp. for 1% Change in Watts.	Lumens per Watt.
Untreated carbon...	1890 C.	0.76	9.0
Helion............	1850	0.75	9.2
Treated carbon.....	1855	0.74	9.5
Gem...............	1855	0.76	9.4
Tantalum..........	1765	0.65	10.0
Tungsten..........	1740	0.67	11.5
Osmium...........	1800	0.65	12.5

The authors have been unable to determine the true temperature at which a color match with a black body can be obtained with any material except platinum, and, therefore, they are unable to state as to what extent the higher efficiency of the metallic filaments is due to selective radiation, although the results would indicate that in the case of osmium from 30 to 40 per cent. of the increased efficiency over a carbon-filament lamp is due to selective radiation.

Questions and Answers

Question.—*In stringing overhead electric lines, where telephone or telegraph wires are on the same poles, which should be above? Give reasons.*

Answer.—High tension wires, such as those for series work and primary circuits, should always be placed above telegraph and telephone circuits. Low-tension wires may, with advantage, be placed below or above them, as may be most convenient. This depends largely on the relative numbers of the different kinds of wires on the poles. In either case, there should be a good clearance between the groups.

The reasons for carrying the slenderer telegraph or telephone conductors below the high-tension wires are obvious. They are more liable to trouble and breakage than the high-tension wires, and if dropped across the latter would lead high-tension current into offices and residences over wires having low-insulation resistance, and the results to the public might be very serious. On the other hand, if telephone or telegraph wires breaking fall on low-tension conductors, they will simply be burned off, if the insulation is bad. If the insulation is good, the trouble on the telephone line will probably be corrected before anything further happens.

Another reason for placing the telephone or telegraph wires below is that the lineman for these circuits will not have to climb through high-tension wiring.

Still another reason is that there are more changes being made in telephone and telegraph wires, especially in the former, than in high-tension circuits, and there is less risk in attending to this work if the high-tension wires are above.

Question.—*A statement has been made that an iron bar driven into the earth makes a better ground for a lightning arrester than an iron pipe of the same length and area, the reason given being that the pipe acts like a choke coil, and therefore offers more resistance to the passage of the lightning discharge than does the bar. Is there anything in this claim?*

Answer.—We think not. Either the pipe or bar, if driven sufficiently far into the ground to insure contact to permanently damp earth, will make a satisfactory ground. In fact, the pipe might be considered as more advantageous, because of the larger surface in contact with the earth, due to its larger diameter. In either case, the main point is to reach damp earth, and to be sure that the ground lead is properly and permanently attached to the pipe or bar.

We think that the claim that the pipe ground acts as a choke coil came from the practice of permitting the pipe to enclose the ground wire from a depth of, say, a few inches under ground to a height of 6 or 7 ft. above the ground. This is the arrangement that would give the choke effect unless the precaution is taken to metallically connect the ground wire and the pipe. Otherwise the arrangement of the ground wire with its insulation and the pipe surrounding it forms a condenser, which would have the effect of materially increasing the resistance to discharge.

Question.—(a) *Are transformers in which the oil is not up to the full level any more apt to be struck by lightning than those in which it is? If so, why?* (b) *How often should oil be changed?*

Answer.—(*a*) A transformer which has not its full amount of oil is no more apt to be struck by lightning than any other transformer. It is, however, very much more apt to be injured when it is struck than one which is properly filled, and so more liable to come to the notice of the operator. The reason is that the principal strain in a transformer from a lightning stroke comes on the first turns adjacent to the lead by which the discharge enters. Now, in most transformers the leads go out at the top, and when the oil is unduly low so that a portion of the coils is exposed to the air, the condition arises that the very part of a transformer most exposed to the strain has the weakest insulation. This being the case, the natural result is indicated by records which show that on systems operating transformers with the oil at various levels nearly all the burn-outs from lightning occur in transformers with less than the normal quantity of oil. These being weakest let go first.

(*b*) When it becomes necessary. The oil in transformers should be regularly inspected at intervals. Just how often these inspections should be made depends upon the climatic and other local conditions. When the inspector finds that oil is wet or dirty it should be changed at once. A good way to determine if there is moisture in the oil is to lower a glass tube into the case with the finger on the upper end. When the lower end of the tube reaches the bottom of the case raise the finger, when a little oil will flow into the bottom of the tube, and by closing the upper end an unmixed sample of the oil at bottom of the case may be obtained. There are several well-known and simple tests for moisture in the oil which can be applied to the sample.

Question.—(a) *How is a meter rated?* (*b*) *If it is correct on light loads, will it be so on half and full loads.*

Answer.—(*a*) Meters are rated according to the load they are designed to measure. Ordinary types of direct-current meters, in common with other meters, are liable to overheat if too much energy is passed through them. Overloads may also injure the meter magnetically.

The best meters are designed with liberal overload limits. At the same time there must be a limit, and most companies have fixed this at 50 per cent. In some cases they have been known to stand very much greater overloads, but the practice of causing them to do so for any great length of time is not to be commended.

(*b*) It does not follow that the meter which is correct at low loads will be so at half or full load. The probability that it will be depends on the causes of variation in that particular design of meter.

The control of accuracy of the meter at different points on the load curve varies with the make and type, so that nothing certain can be said in this connection without knowing what sort of meter is under discussion.

Question.—*What is the effect of sinking a wire into a slot in the laminated iron core of an armature?*

Answer.—On a smooth core armature the conductors are not entirely surrounded with iron, and the force between them and the magnetic field in which they move is exerted largely upon them, as well as upon the iron upon which they rest. This force tends to cause the conductors to slip over the surface of the armature. If the conductors are sunk into slots in the core they then have iron on three sides instead of one, and are also effectively prevented from slipping. Most of the pull is now exerted on the teeth between the slots and the construction is thus much stronger mechanically and magnetically. Also by placing the conductor in the slots the air gap between the armature and the fill may be reduced to a minimum, which means a more economical excitation. The disadvantage of sinking a wire into the slot is that the self-induction of the armature coil is increased, and this tends to defective commutation, but in the best modern machines these difficulties have been successfully overcome.

The National Electric Light Association will hold its 32d annual convention at Atlantic City, June 1st, 2d and 3d.

The 110,000 -Volt Transmission Line of The Grand Rapids-Muskegon Power Company

Considerable interest has been aroused by the 110,000-volt transmission line of the Grand Rapids Power Company which, now that it has been operating satisfactorily for six months, has proved the entire practicability of this voltage for long-distance electric transmission of power. This transmission line runs between Grand Rapids and the Croton Dam, Michigan, and is 50 miles in length, and is carried on triangular steel towers which are approximately 53 ft. in height over all and 43 ft. 8 in. from the ground to the lowest cross-arm, and which were designed to give a 40-ft. clearance between the line wire and ground. The towers shown in Figs. 1 and 2 weigh approximately 1700 lbs. each and provide a minimum spacing between the insulator hangers

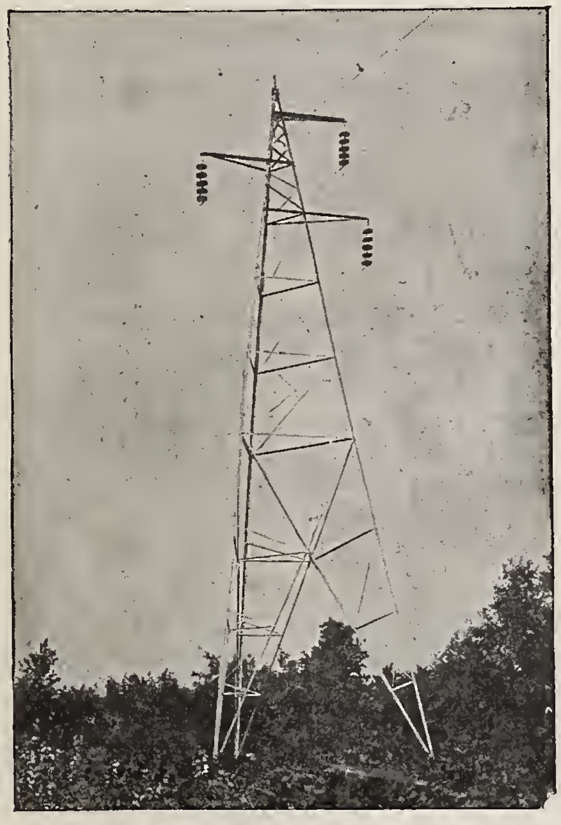


Fig. 1.—TRANSMISSION TOWER

of 8 ft.; they are placed on large concrete anchors buried in the ground, and are spaced 528 ft. apart on tangents. The anchors consist of 3-in. angle steel, 7 ft. 10 in. long, encased in concrete. The anchors each extend about 10 in. below the bottom of the concrete in which they are encased, thus securing a ground for the transmission line.

The insulators are of the standard General Electric disk pattern, the suspension type being used for a straight support and the strain type for pull-off curves. Five of these 10-in. disks are used in series, the arrangement being very clearly shown in Fig. 3. Each disk is rated at 25,000 volts.

The line transmits 10,000 kw., the conductors consisting of No. 2 stranded hard-drawn copper wire with hemp center. The lines are spaced 8

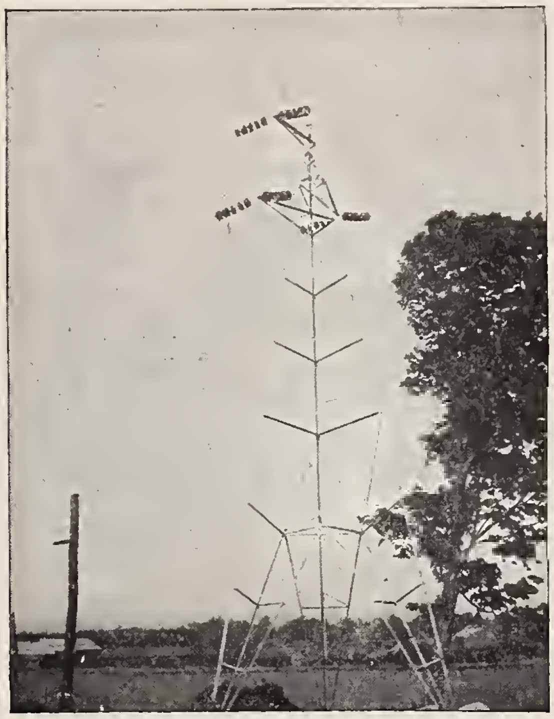


Fig. 2.—TOWER AT AN ANGLE

ft. apart and are entirely without transposition throughout the whole length. No guard wire is used.

The lines are brought into the stations through porcelain insulators and are connected directly to the high-tension transformers, which are delta-connected on both sides. There are no switches of any kind, the control being by means of generator field switches.

The pressure was first applied to the transmission line on July 18, 1908, and it was noticed that the line was a little noisy at the working pressure of 110,000 volts, while at night the atmospheric discharge was distinctly visible. Wattmeter ratings on the empty line, after deducting the core losses of the step-up transformers, seemed to indicate a constant loss on the 50 miles of line of from 20 to 25 kw.

Fig. 3.—DETAIL OF INSULATION

Drying Transformer Oil

The weakening effect of the presence of even a small amount of moisture on the insulating value of transformer is well known. A small fraction of a per cent. of moisture may reduce the insulation to a fraction of its value when the oil is perfectly dry. There are a number of different ways of separating the water, nearly all of which depend on the introduction of some water-absorbing agent such as dry air. Chemists, however, have long known that sodium in the metallic form has a great affinity for water, and have used it to remove the last traces of moisture from substances under treatment. Recent experiments have shown that this agent can be used to remove more than the last trace of water.

In transformer oil it will sink unless dragged to the surface by hydrogen gas. With water it reacts to form caustic soda and hydrogen. If very much water is present the caustic soda dissolves and in the presence of oil forms a second layer. If very little water is present the caustic soda is formed on the surface of the metallic sodium and may be removed when removing the sodium. When the sodium surface becomes covered with caustic, it is advisable to remelt under oil, not letting the temperature rise above 120° C. (248° F.). After cooling and getting into the shape desired, it is again ready for use for drying more oil. Sodium should always be kept under a good transformer oil. One method which has been used with some transformer oils has been as follows:

The oil on the granulated sodium is poured off and a good transformer oil poured over the metal. To the oil which is to be treated, and which is put into an open tank or barrel, the sodium is added at first very carefully, about one ounce to the barrel. If much hydrogen is evolved, this will be conclusive proof that there is much water in the oil, and the balance of the sodium should be added carefully and in small amounts. The amount which is to be added depends upon the oil, but as a rule one pound to the barrel is usually much more than is required. The oil is then stirred up three or four times a day for a minute at a time. After several days the oil may be removed and tested, but the longer it remains over the sodium the better it oil becomes.

Another method used is to put the sodium in the form of sticks in a cylinder of iron wire of about 28 mesh and hang the cylinder in the oil. This method may be used directly with the static transformer which is in use. The only precautions required being those familiar to all electricians in the avoidance of short circuits.

The result of the above treatment has been to raise the breaking point of a given sample of oil from 3000 volts to 20,000 or higher. This has been done on a large scale by some of the great power companies at Niagara.

The February Technical Press

Leading Articles of General Technical Interest

Commercial

"The White Coal of Sweden," John George Leigh.

A carefully-written article on the water development of Sweden profusely illustrated and provided with maps and tables. Among the notable features described are a rigid governmental control, and the great variety of industries which are supplied by the hydro-electric companies.

The horse-power of water-driven generators now installed reaches 176,000, which is considerably more than the nation's total generator power from steam-driven plants.—*Cas. Mag.*

"Railroad Electrification," Philip Dawson.

A general discussion of the present status of the electrification of steam railroads throughout the world. The records of the single-phase, polyphase and direct-current lines are given, and the writer concludes that in general the single-phase system will be adopted on main-line work outside all terminal stations.—*Elec. Rev.* (*London.*)

"Trolley Development in the United States," G. E. Walsh.

A paper describing the principal features of and discussing the future developments of interurban railroads in the United States.—*Cas. Mag.*

Detail Apparatus

"Application of Automatic Controllers," D. E. Carpenter.

Continues description of the latest forms of controller for direct-current motors.—*Elec. Jour.*

"Meter and Relay Connections," Harold W. Brown.

Continues series giving diagrams showing the connections of different types of meters.—*Elec. Jour.*

Electric Railways

"Automatic Electric Railway Signals," Wm. K. Waldron.

An account of the latest development in electric railway signals for third-rail direct-current roads as manufactured by the Union Switch and Signal Co., of Swissvale, Pa.—*Elec. Wld.*

"Power Plant Extension of the Boston Elevated R.R. Company."

Tells of the growth of the power-station requirements of this well-known road, and describes some features of the new additions to the Lincoln Wharf and the Hartford Stations. —*Elec. Ry. Jour.*

"The Development of a Small Road."

A description of the organization and the management of the Sheboygan Light, Power & Railroad Company, of Sheboygan, Wisconsin, and a story of the methods used in the road's development.—*Elec. Ry. Jour.*

"The Montreux-Bernese Oberland Railroad." B. F. Herschauer.

An illustrated description of a 40-mile, 750-volt, direct-current railroad in western Switzerland. The road has heavy grades, and a combination of vacuum and electro-magnetic track brakes are used for train control.—*Elec. Rev.*

Management

"Commercial Department of Rochester Railway & Light Company," Wm. H. Stuart.

A description of the methods of a progressing company in handling complaints, advertising and rate charging. Curves and tables of rates and discounts are given.—*Elec. Wld.*

"Financial Problems Confronting the Boston Elevated R.R. Company," C. S. Sergeant.

A full and authoritative discussion of the financial problem as it presents itself under the conditions obtaining in Boston. A chart is given showing the relation of expense to gross income from 1888 to 1908. The conclusion is obvious that with the increase in the cost of operating the system, and the constantly increasing fixed charges, no lessening in the price of the company's service is to be thought of, as all profit figures show a material reduction during the last few years.—*Elec. Ry. Jour.*

"The Economical Development of Toll Territory," Frank R. Fowle.

The writer finishes his discussion of the latest methods of handling a telephone territory.—*Elec. Rev.*

"The Problem of Reducing Accident Damages," F. W. Johnson.

Continues the discussion of the latest methods of preventing street car accidents by educating the public concerning certain common-sense precautions to be used in street car travel. —*Elec. Ry. Jour.*

Measurements and Tests

"Comparative Tests of Transformers," A. C. Scott.

An account of a test of the transformers of five leading manufacturers, both of the shell and core type variety. A page of curves giving results of the test in the shape of efficiency, temperature rise and core loss for the five shows the variation in the practice of different designers. The efficiency curves are the most similar and all come well within the standard requirements of the A. I. E. E.—*Elec. Wld.*

"Testing Outfits for College Laboratories," E. P. Edwards.

A description of the various types of generators, transformers and other electrical apparatus developed for laboratory use. The distinguishing feature of these experimental machines is their great flexibility. Thus one machine is designed to operate as a rotary converter, double-current generator, direct-current generator, alternating-current generator, direct-current motor, synchronous motor and an inverted rotary.—*Gen. Elec. Rev.*

Power Plants

"A Low Head Hydro-electric Development," S. Rice.

A description of an interesting plant at Milford, Me., which develops 12,000 h.p. under a 20-ft. head.—*Power.*

"A 60-Cycle, Gas-Driven Power Station," J. R. Bibbins.

A record of the operating experience of a 500-kw. gas-driven plant of the Union Switch and Signal Company, near Pittsburgh, and a description of the new plant being erected there, illustrated with indicator cards and other records of the plant. A table of the cost of power with fuel at 15 cents per 1000 cu. ft., and a loading factor of 50 per cent., gives total operating cost at 0.58 cents per kilowatt-hour and a total cost of 0.71 cents per kilowatt-hour.—*Elec. Jour.*

"Italian Power Plants," S. Q. Hayes.

The illustrated description of various power plants in northern Italy, covering especially the switchboard practice there in force. Some of these were illustrated in the December issue of The Electrical Age.—*Elec. Jour.*

"Kokomo, Marion & Western Traction Co.," Alfred Cummins.

A description of the new lighting and power plant of the above company which is interesting, as an example of the very best type of a modern power plant.—*Ind. Prog.*

"McCall's Ferry Hydro-Electric Power Development."

An illustrated description of the hydraulic features and power-house building of the big McCall's Ferry power plant, 40 miles north of Baltimore.—*Elec. Rev.*

"Representative Data from Electric Power Plant Operation," H. S. Knowlton.

A careful study of the cost of producing power in seven cities of New England showing how local conditions affect the total operating cost in the cases given which cover large central stations. The total operating cost varies from .82 to 1.62 per kilowatt-hour. The vital importance of keeping accurate records is emphasized.—*Eng. Mag.*

"The Urft Valley Energy Transmission Plant."

An illustrated account of a well-designed hydraulic transmission plant in Southern Germany. A fine sample of the best quality of recent work abroad.—*Elec. Wld.*

Prime Movers

"Modern British High-Speed Engines," J. Davidson.

Describes the latest work of the British manufacturer in high-speed engines for direct-connection to generators. The performance, curves and records given compare favorably with those of similar machines in this country.—*Power.*

"Modern Steam Condensing Apparatus," J. B. Foster.

A description of the various improvements in the steam condenser forced by the development of the steam turbine.—*Ind. Prog.*

"Surface Condensers for Steam Turbines," E. Josse.

A discussion of the performance of a well-designed condenser and its auxiliaries. Gives the results of a series of condenser tests made at Charlotteburg, Germany.—*Power.*

Theory

"Alternating Currents and Their Application," Edson R. Wolcott.

Continues through the month, being devoted principally to various types of transformers.—*Elec. Rev.*

"Energy in a Pound of Steam," Fred R. Low.

Analyses the energy contained in a pound of steam, giving curves and tables showing the changes produced in expanding from 150 lbs. pressure to 27½ inches of vacuum.—*Power.*

"Heat Conductivity in the Equalization of Furnaces," Carl Hering.

An investigation of the conductivity of various materials used in furnace walls, and suggestions for improving their heat insulating qualities.—*Elec.-Chem. & Met. Ind.*

"Short Circuits in Alternators," E. J. Berg.

A study of the action of well-designed alternating-current generators on shirt circuit. It is well illustrated with oscillographic records.—*Gen. Elec. Rev.*

"Solid Rectifiers," G. W. Packard.

A description of experimental work on the little known subject of the unilateral conduction of certain solids. A curve is given showing the characteristics of various solid rectifiers. The writer concludes that at present there is no satisfactory theory for an explanation of these phenomena, and calls attention to the possibilities that are contained in their further study.—*Elec. Rev.*

"Thermodynamics," Chas. P. Steinmetz.

Continues the discussion of the equation of molecular motion.—*Gen. Elec. Rev.*

"Variable Ratio-Convertors," Chas. P. Steinmetz.

The fourth of a series of articles dealing with the equations used in the design of the split-pole convertor.—*Gen. Elec. Rev.*

Transmission

"Electric Transmission," Alton D. Adams.

An article giving a general description of long-distance high-tension transmission development in various parts of the earth, and a curve showing the relation between the length and voltage of transmission lines of some of the principal systems.—*Cas. Mag.*

Utilization

"Industrial Engineering," H. W. Peck.

A practical paper in the application of the motor to machine tool work, cotton-mill drive and other typical industries that are furnished with power by the Rochester Railroad and Light Company, to which the author is electrical engineer.—*Elec. Jour.*

"Series Tungsten Lighting," Henry Schroeder.

An article on the features of the series tungsten lamp, with curves and tables illustrating the performance and economies of this form of lighting.—*Elec. Rev.*

"Street Lighting for Interurban Ry. Currents," G. N. Chamberlain.

This paper describes the most up-to-date method of street lighting from railway circuits by means of the magnetite arc lamp.—*Gen. Elec. Rev.*

"Street Lighting in Rio Janeiro," A. H. Keleher.

A well-illustrated description of the way the public lighting of Brazil's metropolis has been handled. No city, save perhaps Berlin or Mexico, is better lighted.—*Elec. Wld.*

Miscellaneous

"Development of the Surface Condensers," W. O. Rodgers.

A well-illustrated article giving the history of the surface condenser from the time of Watt down to the present. —*Power.*

"High Pressure Steam Piping System," Wm. F. Fischer.

A practical article relating to the various points to be considered in the design of a high-pressure steam-piping system including the ever-present expansion and vibration problems.—*Power.*

"The Manhattan High Pressure Fire Service."

The well-illustrated description of the New York high-pressure fire service which is operated from electrical centrifugal pumps.—*Ind. Prog.*

A Combination Volt-Ammeter

A compact little instrument for the measurement of voltages from zero to six, and of currents up to 30 amperes, is being turned out by the Connecticut Telephone & Electric Company, Inc., Meriden, Conn. The voltmeter side is primarily designed for storage bat-

tery tests; the ammeter side for testing dry and wet batteries. The 1909 type has an etched medal instead of the paper one generally used, and the entire interior construction has been improved, it now being made up on the dead beat principle. The meter is accurate, durable and very reasonable in price, and should find a large application.

News Notes

The Holophane Co., of New York, in its latest bulletin calls attention to the increasing use of its product in factories, clothing stores and in other classes of industrial services.

Catalogue F of the Hart and Hegeman Manufacturing Company, of Hartford, Conn., gives cuts and illustrations of the many high-class types of switch and wire details manufactured by this company. The attached views show details of their new floor plug.

The Nernst Lamp Company has secured the contract for lighting the large, fireproof, steel, brick and stone department store of McFadden Brothers, of Wheeling, W. Va. This building will be lighted throughout by the single glower Westinghouse Nernst lamp, mounted on special three-arm fixtures.

The National Electric Contractor's Association will hold its annual convention in Toledo, July 21st, 22d and 23d. The program will include a banquet and other entertainment features, in addition to the usual discussion of subjects pertaining to the trade. It is expected that between 300 and 400 electrical contractors will be in attendance.

The Stave Electric Company, of New York, is establishing a number of branches throughout the West for pushing the sales of the flaming arc lamp, of which it is the importer. Offices are being opened in Chicago, Pittsburgh, Davenport, Cleveland, Philadelphia and Indianapolis. The company reports a lively interest in flaming arc lamps throughout the west.

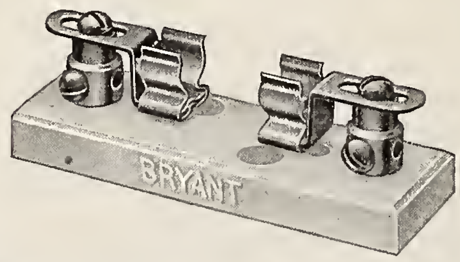
The annual convention of the branch managers of the Crocker-Wheeler Company was held at Ampere, N. J., Feb. 8th. The same evening the managers were entertained at dinner by the Machinery Club of New York. They report fairly good business for small machinery, and that many projects are being considered for the installation of industrial plants.

The Spencer Turbine Cleaner Company, of Hartford, Conn., has recently closed contracts for installing two of its cleaners in the new Fifth Avenue Building, at the corner of Twenty-third Street and Fifth Avenue, New York. One of these cleaners is 30 h.p., 12 sweepers, and the other 20 h.p., 8 sweepers. This concern will also place two 25 h.p., 10 sweeper cleaners in the Emigrant Industrial Savings Bank Building, New York.

Nilson, Miller Co., of Hoboken, N. J., has been incorporated with capital of $25,000. They are located at 1300 Hudson Street, in the shop formerly occupied by W. D. Forbes & Co., and will conduct an engineering and general machine shop business, making a specialty of designing and building, to order, electrical apparatus, gasoline engines, etc., for commercial, vehicle, marine and stationary use. Also experimental work and special machinery.

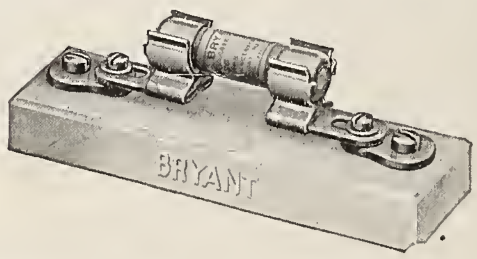
Dossert & Company, of New York, have received an order from the National Electrical Supply Company, of Washington, D. C., for a large number of Dossert solderless connectors, cable taps and terminal lugs specified by the Isthmian Canal Commission; also an order from the San Francisco Gas & Electric Company for 300 cable taps and from the Fairbanks-Morse Electrical Mfg. Co., of Indianapolis, Ind., for 100 Dossert insulating joints.

Among the recent orders taken by the Crocker-Wheeler Company, of Ampere, N. J., is one for a 250-kw. motor-generator set for the Tennessee Coal, Iron & Railroad Co., at Ensley, Ala. It will consist of a 250-kw., 275 volt, direct-current generator driven by a 6600 volt, 3 phase, 25 cycle synchronous motor and will be used as an exciter. Another order is one for about 50 h.p. of small elevator motors, purchased by the Haughton Elevator & Machine Co., of Toledo, Ohio. Yawman & Erbe, of Rochester, N. Y., have also placed orders for a number of 2/5-h.p. motors for use on some of their specialties.



Bryant Company's Fuse Adapters

The accompanying cuts show the fuse adapter of the Byrant Electric Company, of Bridgeport, Conn. These adapters permit the use of National



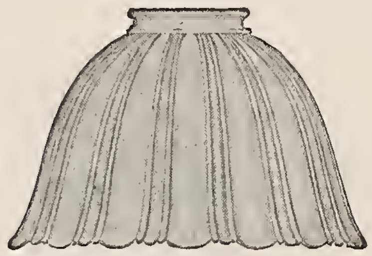
Electric Code Standard Fuses on unapproved bases. They thus play the same rôle in the fuse line that the well-known socket adapters do for lamp sockets.

"Opalux" High Efficiency Reflectors

The increase in the use of high-efficiency lamps has presented a new problem in electric lighting—that of securing a proper diffusion of the intense light rays which are developed by these lamps.

There is no economy in the use of a powerful light if the increased volume of light is massed at a point where it is not required. It is only by a proper diffusion of the light which is furnished by the new high-efficiency lamps that real benefit is obtained.

The Pettingell-Andrews Company, of Boston, are now placing on the market an artistic glass reflector which they claim is especially suitable



for high-efficiency illumination. They have given this reflector the trade name of "Opalux." The manufacturers state that "Opalux" represents a combination of science and art to produce an ideal system of diffusion for high-efficiency lamps.

In appearance this shade is a clear blue-white, with a smooth outside surface and a patented "Egg Shell" inner reflecting surface, making it easy to clean and not liable to readily become soiled. It is perfectly translucent, transmitting soft color tints that illuminate the ceiling with a warm glow entirely free from sharp contrasts. It does not have sufficient direct reflection to produce perceptible glare; but gives an intense light with a brilliant pearly luster, slightly opalescent.

We show herewith a cut of the Type S or "Bowl Shape" Reflector. The "Flat Shape" is also being made for use with very high ceilings.

The Postoffice Department at New York City is adopting Western Electric intercommunicating telephones as a time and labor-saving device. At the Lenox Avenue and Forty-fifth Street station an intercommunicating set with eleven stations has been installed, and is proving highly satisfactory.

What is believed to be the first step toward equipping its whole system with the telephone for train dispatching purposes has been taken by the Denver & Rio Grande Railroad. It has placed an order with the Western Electric Company for equipment covering 15 stations for 45 miles of copper metallic circuit.

Southern Electrical Industrial Exposition

In view of the fact that the Southern Electrical and Industrial Exposition is to be held in Louisville, Ky., April 12th to 24th, manufacturers of electrical appliances and machinery are particularly interested. This is due to the fact that the exposition is expected to have the effect of stimulating interest in the use of electricity, and to result in a much wider appreciation of its possibilities by the South. Exceptionally low railroad rates will bring a record-breaking crowd from every section of the South, and will enable the manufacturers to reach a class hitherto hard to approach.

The exposition will be held in the First Regiment Armory at Louisville. The armory has a floor space of 54,000 sq. ft., and is the greatest building of the kind in the United States. It has no vertical supports, the roof being sustained by mighty steel arches, so that the wide sweep of the floor is ideal for exhibition purposes. Many exhibits have already been arranged for by the leading electrical manufacturing concerns of the country, and it is certain that the representation will be general. General industrial development will be shown, along with the special progress and interest attaching to the field of electricity.

The Southern Electrical and Industrial Exposition is a successor in a way of the Greater Louisville Exposition, held in Louisville in 1907, when 150,000 people saw the displays. Fully a quarter of a million, coming mainly from the South, will be there this time it is believed, and that fact makes the opportunity to reach them directly and effectively one that should not be overlooked.

Meetings of Illuminating Engineers' Societies

The next meeting of the New England Section of the Illuminating Engineering Society will be held in the Auditorium of the Edison Building, 39 Boylston Street, Boston, Tuesday evening, March 16, at 7.30 o'clock. A very interesting and instructive paper will be read on "The Simplification of Illumination Problems Through the Conception of Light Flux," by J. S. Codman.

L. D. Gibbs,
Secretary, N. E. Section,
Ill. Eng. Society.

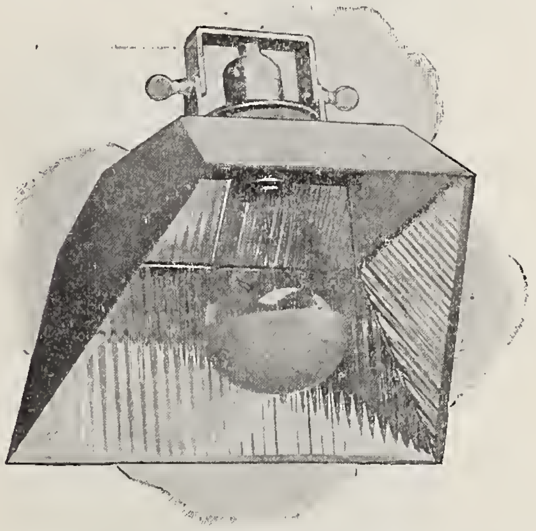
The next regular meeting of the New York Section of the Illuminating Engineering Society will be held in the Engineering Societies Building, 29 West 39th St., New York City, on Thursday, March 18th, at 8.15 P. M. Two papers will be presented, namely, "The Mathematical Theory of Finite Surface Light Sources," by Mr. Bassett Jones, Jr., and "Illuminating the Editorial Offices of the New York World," by Mr. Albert J. Marshall. These papers treat on both the theoretical and practical sides and will be taken up and discussed.

Non-members are most cordially invited to attend and participate in the discussion.

Window Lighting for Easter

Probably no part of the lighting equipment of stores provides for greater brilliancy than that in the store windows, and it is here that the high efficiency of the tungsten lamp has met with its greatest successes.

But it is possible to still greatly increase the efficiency of this unit by utilizing all of the light radiated from the lamps in every direction and diverting it to some useful direction with a suitable reflector.



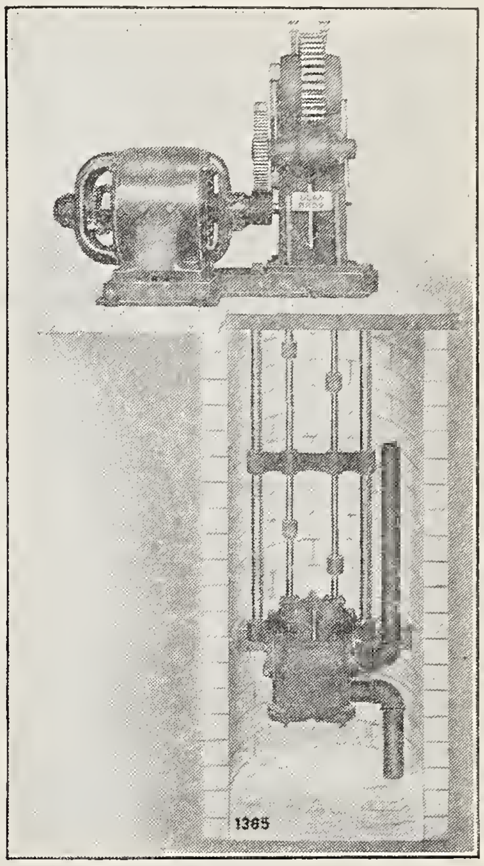
This is accomplished by the Wheeler Reflector Company's (Boston) No. 65 Tungsten Adjustable Window Reflector shown in the illustration above. This is mirror-lined and designed so that the upward radiated light is all reflected down, that from three sides forward and down, while that from the remaining side is radiated horizontally without interference.

But the especial merit of this device is its wide range of usefulness. Every change in the window trimming to be fully effective necessitates a change in the direction of the light. The above reflector has a hinged holder which is attached to the stem of the fixture above the nozzle of the socket which permits the adjustment of the reflector to suit periodical changes in the window trimming, while the lamp remains fixed in a vertical position.

Contractors meeting severe competition can offer an effective argument for preference in the award of business by the results they can achieve by means of this device and the approaching Easter window displays seem to afford an excellent opportunity therefor.

Dean Bros.' Vertical Electric Well Pump

This pump is designed for wells of considerable depth, where the pump cylinder cannot be placed on the floor above well. The pump cylinder is duplex and double-acting so that there are four cylinder discharges to each revolution of crank shaft, thus producing a steady, equitable flow of water. The cylinder is suspended by rods from the base of frame at top of well, and is also bolted to a cross timber fixed across the well.



The driving head of pump is placed on a sub-base with the electric motor over well. There are two reciprocating piston rods that connect with the pump cylinder which are driven from cross-heads on the frame. The cross-heads are connected to the crank pins of driving-head through connecting rods. The crank pins are set quartering so that the load on motor is quite uniform. It makes a very complete and efficient outfit for pumping from wells that are even 100 ft. deep. This duplex, double-acting pump is economical both as to first cost and expense of operation. There are many places where a steam pump or a belted pump cannot be used. For example, where the well is at considerable distance from the power-house, or where the only available power is electricity. The increasing use of electricity as a motive power has made it necessary to produce special patterns of pumping machinery for motor drive.

An attractive folder detailing the excellence of its tungsten lamp has been issued by the Buckeye Electric Company, of Cleveland, Ohio.

Personal

Mr. H. E. Lavelle has severed his connection with the Electrical Supply Company.

Mr. L. A. Ferguson, President of the A. I. E. E., has been elected one of the directors-at-large of the Chicago Association of Commerce.

Mr. H. A. Robbins, formerly assistant engineer of the Brooklyn Rapid Transit Company, has been appointed superintendent of motive power.

Clifton R. Hayes, superintendent of the Fitchburg Gas and Electric Light Company, of Fitchburg, Mass., has been appointed general manager of the company.

Mr. L. R. McCleary, of Niagara Falls, New York, formerly with the Ontario Power Company, has been appointed manager of the Falls Power Company at Welland, Ontario.

Governor Hughes has recommended Messrs. John E. Eustis and James E. Sague to succeed themselves in the Public Service Commissions of the First and Second districts, respectively.

Mr. C. G. Young, formerly with J. G. White & Company, has opened an office as consulting engineer at 60 Wall Street, New York City. Just now he is in the Far East on a business mission.

Mr. P. N. Jones, electrical and mechanical engineer of the Pittsburg Railroads Company, has been appointed general superintendent of the Company to succeed Mr. John Murphy, who becomes assistant to the president.

Mr. E. G. Acheson, a well-known electrical engineer and inventor of carborundum, who is also President of the American Electro-Chemical Association, was recently made a doctor of science by the University of Pittsburg.

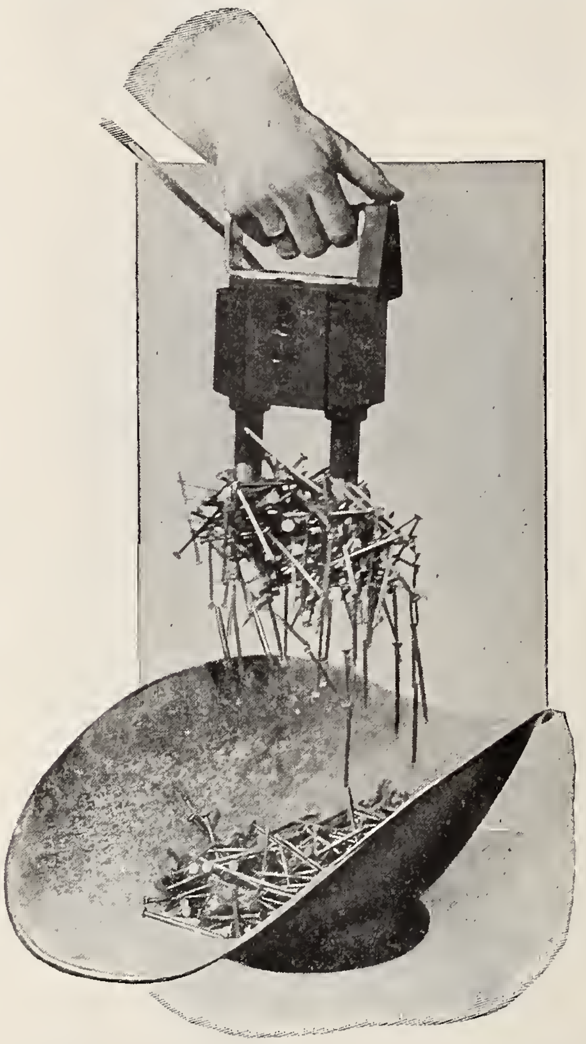
Mr. L. G. Nilson, Chief Engineer of Strang Gas Electric Car Co., of No. 15 Wall Street, New York City, has been elected president of Nilson, Miller Co., of No. 1300 Hudson Street, Hoboken, N. J. He will continue as consulting engineer for the Strang Co.

Mr. L. C. Fritch has been appointed consulting engineer for the Illinois Central Railroad, and will be in charge of its electrification work. He has had charge of the investigation which the Illinois Central has been making of the feasibility of electrifying the Chicago terminals.

Mr. C. O. Mailloux, the well-known consulting engineer, who went abroad last fall to represent the A. I. E. E. at the International Electric Congress, at Marsailles, has returned after an extended trip, in the course of which he not only acted in a professional capacity for a European syndicate for electrical projects, but also made a careful study of the latest developments in the electrical field in central and eastern Europe. Shortly before returning he delivered a course of lectures in Paris on electric train movements and the electrification of steam roads.

A Handy Magnet

Something new in the lifting magnet line has just been placed on the market by the Cutler-Hammer Clutch



Co., of Milwaukee, whose large lifting magnets are widely used in the iron and steel industries for handling pig-iron, scrap, etc. The new device is a hand-magnet weighing only about seven pounds but capable of lifting castings of from 10 to 15 times its own weight.

The magnet is designed for operation on 110-volt, direct-current circuits and is furnished with drop-cord and attachment plug so that it may be readily attached to any ordinary lamp socket. The push-button mounted on top of the magnet and operated by the thumb closes the circuit to the coils and makes the magnet operative. On releasing the button the poles become demagnetized and the load is released.

The first of these little magnets was built for use in the Cutler-Hammer Clutch Co.'s own shop, where it proved so useful and attracted so much attention from visitors that it was decided to manufacture it in quantities for the market.

It seems to be capable of many useful applications. In machine-shops it is used for clearing chips and borings out of the machinery or removing them from parts of the work not easily accessible, as for instance, from the bottom of a deep cylindrical casting. Dropped tools, bolts, boring bars, etc., are easily recovered with the aid of the magnet from places from which it would be difficult to fish them by ordinary means.

Book Review

"Electric Motors," by Norman G. Mead. A compact handbook on the subject of the installation, care and management of electric motors, together with a discussion of their theory, for the use of practical men. 159 pages. McGraw Publishing Company, $1.00 net.

"The Principles of Alternating Currents" for Students of Electrical Engineering, by Edgar T. Larner, A. I. E. E., of the Engineering Department, General Post Office, London. This book is an effort to present the discussion of alternating current problems in a non-mathematical fashion; that is, the methods involved do not go beyond elementary algebra. It is well illustrated with diagrams and will meet the needs of a large and increasing class of students of the subject. 136 pages. D. Van Nostrand Company, $1.50 net.

"Steam Power Plant Engineering." By G. F. Gebhardt, Professor of Mechanical Engineering at Armour Institute of Technology. This book is the compilation of a series of lectures to senior students in an engineering course. It is logically arranged, starting with fuels and combustion. It then takes up boilers and boiler-room auxiliaries, coal and ash handling, natural and mechanical draft, continues with steam engines and turbines and engine-room auxiliaries, and concludes with a careful study of operation, costs and tests. Two plants, one of the turbine type and one of the reciprocating type, are described by way of examples. A large number of illustrations and curves and more than 110 tables are given. The information furnished is well arranged and up to date. The book is a valuable contribution to the literature of the subject and should have a wide sale. 816 pages, John Wiley & Sons, $6.00.

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NOTICE TO ADVERTISERS

Insertion of new advertisements or changes of copy cannot be guaranteed for the following issue if received later than the 15th of each month.

CONTENTS

Concrete Poles

For some years past there have been many predictions that the time would come when reinforced concrete would supplant the use of wood and steel and leave the supply of those materials free for utilization in the fields that are peculiarly their own. The shortage of the timber supply caused largely by the strenuous efforts made in the United States to burn up at least a few hundred million dollars' worth of buildings every year has been pushing the question more and more to the front.

By means of much costly experiment and experience in the numerous details involved in the economical production of concrete forms, the point in the process seems to have been reached where a small house of reinforced concrete can be built for approximately 25 per cent. more than a wooden house of the same size and style. When the insurance and the value of safety for the furnishings and contents of the house—not to speak of the security of the lives of those who live in it—are taken into consideration, the concrete proposition is coming to appeal to the builder, even of the most limited means, and so we see that the number of concrete dwellings is increasing by leaps and bounds.

Another great source of waste of wood is the use of wooden ties, and it is interesting to note that the long discussed steel tie as well as its newer relation, the reinforced-concrete tie, is beginning to make real progress. There are many miles of both kinds in the railroads of the United States to-day, and their use is increasing at a rapid rate.

The coming of the reinforced-concrete pole for all purposes where wooden and steel poles are now used is just as certain as the coming of gas-engine-driven battleships or any other obvious development in the field of engineering. The shortsightedness and waste of the use of wooden telegraph poles has just been forcibly set forth by the complete breakdown of the pole lines of the telegraph companies between Philadelphia and Washington by the sleet storm of Inauguration Day.

There is not the slightest doubt that the wretched performance exhibited on that occasion is liable to be duplicated in any northern section of the United States at any time. Nor is there the slightest doubt that the whole breakage, not only of the poles but of the wire also, could have been and would be absolutely prevented by the adoption of up-to-date and scientific methods of pole-line construction and wire suspension. No one acquainted with the facts of the case will deny this. It is merely a matter of crystallized brains in the management being unable to adjust themselves to new conditions and the utilization of new means—just as in the navy. Time and a series of such expositions as that of March 4th will be required to force new ideas into practice.

Leaving aside the details of manufacture and suspension by which telegraph lines can be made non-breakable by steel and high wind pressure, the problem of keeping up the poles is easily solved by the use of hollow reinforced-concrete poles such as are elsewhere described in this issue of THE ELECTRICAL AGE. If they are properly made and properly set, with their use not only does the whole supporting structure improve with time, instead of deteriorating at the rate of from 10 to 15 per cent. per year as do the millions of wooden poles in existence to-day, but the item of keep-up and replacement, so far as the supporting structure is concerned, disappears for all time from the company's books, the same as in the case of peculiar local accidents such as collisions, dynamite and mishaps of similar character. How these matters appear in concrete form is shown by the comparison table in the article referred to.

All of the foregoing considerations apply to the companies who have planted the enormous number of poles that are in use for the support of electric transmission lines of both high and low tension.

They are, perhaps, of greater importance in the case of the electric companies than in that of the telegraph and telephone companies, in the same ratio that light and power are more important to a community than the swift transmission of news. Imagine the consequences of as complete a wreckage of a large electric transmission and distribution system in a city as that of the telegraph lines in Maryland. Yet this is just what has to be faced by the electric companies. Their wooden-pole lines are depreciating with the same rapidity as the telegraph. The chief difference in the two situations is that many companies by adopting the steel poles have staved off the day of reckoning and the average transmission and distribution-pole line is somewhat better constructed and very much younger than the average telegraph line.

In the United States, according to the latest bulletin of the Department of Commerce and Labor, there are approximately 1,000,000 miles of telephone-pole lines and 275,000 miles of telegraph lines, being a grand total of 1,275,000 miles, which at 40 poles to the mile means approximately 5,000,000 telegraph and telephone poles. This enormous total does not take account of the thousands of miles owned and operated by the railroad com-

panies. In the whole world there are at least 2,000,000 miles of land-telegraph lines which, at an average of 35 poles to the mile, means 70,000,000 poles which are of wood.

The miles of transmission and distribution-pole line in the United States may be taken approximately at 200,000, of which some 25,000 miles are trolley lines. Deducting 20,000 miles for steel pole and tower-supported line, we have left 210,000 miles of wooden-pole lines which, at an average distance apart of 130 feet or 44 poles to the mile, means about 9,000,000 poles in use for electric purposes.

The average life of wooden telegraph and telephone poles in the United States is elsewhere stated to vary from 12 years for an untreated pole to 20 years for a treated pole. Under such conditions there are annually needed approximately some two millions of poles to supply the present telephone and telegraph lines, and the electric lines will require 400,000 more.

Turning now to the world at large and applying the same considerations, we find that not far from 3,000,000 poles for telegraph and similar lines must be supplied each year and another million or so for railway light and power circuits.

These figures, which are certainly under rather than over the actual facts, show clearly the enormous importance of the question of stopping the waste. The method of lessening it has been taken up with some vigor by the government and a few of the more progressive of the companies involved. The proposal is to increase the life of the wood pole by treatment. This is but a superficial measure. It is the thorough-going Germans who have attacked the problem with characteristic determination, and the first step that is the economical and quick production of an indestructible hollow reinforced-concrete pole, elsewhere set forth in this issue, is what they claim to have accomplished.

Before the light, strong, elastic and everlasting type of pole such as can be evolved by the perfection of processes, there is opened a vast field of usefulness. For not only wood poles will ultimately be displaced but the costly latticed or tubular iron pole which is already left behind in the all-important matter of first cost will gradually give way before the insistent action of the law of economy.

It has been claimed, with some show of reason, that we are the last people in the world to learn this law, and it is therefore fitting to look into an economic possibility that promises as much as does this.

A New Method of Industrial Training

The problem of getting a boy into his life work easily and without loss of time, and the problem of training efficient men in industrial plants, are in many ways opposite views of the same proposition. Many experiments in the solution of these industrial problems have been tried out with more or less success. There is no novelty of view or startling originality of plan in the solution proposed by Herman Schneider, of the University of Cincinnati, except that the boy becomes partially self-supporting and therefore able to continue his purely educational work longer than ordinarily. The plan has one great advantage over the ancient apprenticeship system in that it removes the boy from his work for definite intervals of quasi-compulsory instruction. It provides for one week of school instruction and for one week of shop or factory work. Two boys enter the same shop and alternate each week in their shop work and in their schooling. They are paid apprentice wages while working. Obviously the system is applicable to secondary schools, high schools and the colleges.

The advantages of this plan lie chiefly in the fact that the boy begins to earn money at an earlier age, to form industrious habits under the sharp discipline of a regular shop, to acquire the habit of application to his work, it being impossible to shirk physical tasks without instant detection; and by the constant and close alternation of hand and mind training he attains a symmetrical education in his chosen vocation.

There are some disadvantages to the boy and there are some things not to the liking of the shop owner. A considerable loss of memory of facts occurs even in so short an interval as a week and this fact must make the process of education slower than where the tasks are performed daily. On the other hand, the exercise of the mind in bringing back the work of a week ago must necessarily sharpen the memory and strengthen the mind by compelling it to review after an interval of time a fairly complex and lengthy series of mental acts and physical tasks.

The manufacturer tries the plan because he knows that boys who elect such a plan are on the average above the level of mediocrity, and promise by that token to become better workmen. He is taking chances with human nature, for ambition and ability are stratums of the mind that run not in parallel lines. However, one or two human prizes are of so great value that he is really glad to give the time of a few men to the work of the apprentices and to let a few machines run unproductive. So thoroughly is this matter understood by the big industrial companies that they yearly go prospecting among the colleges for human timber. The Schneider plan ought to lessen their labor by bringing the boys to the manufacturer during the early stages of man-building.

What will be the first electric smelting plant in the world for the production of pig iron on a commercial scale, will be erected in Norway by the Aktiebolaget Elektrometall, of Ludvika, Sweden. The first installation will be built this summer, and includes two iron-ore reduction furnaces of 2500 h.p. each and two steel furnaces of 600 h.p. each. All furnaces will be operated with two-phase current. The plant will later be enlarged by erecting four more iron-ore reduction furnaces of 2500 h.p. each and four steel furnaces of larger size than 600 h.p.

In his annual report, E. H. Utley, general manager of the Bessemer & Lake Erie, says:

"The use of the steel tie continues to increase our confidence in its utility, and I think it is within reasonable bounds to assert that within the next three years the Bessemer road will be double-tracked between Conneaut Harbor and North Bessemer with steel ties, and that by that time the price of first-class white oak wooden ties will be considerably over one dollar each, whereas the steel ties are selling to-day at about $2, and that the management of the Bessemer road can feel that, aside from the few ties that may be destroyed by reason of derailments (and which have a scrap value of at least half of their purchase price), for the next 20 to 40 years the question of tie renewals will not enter into the calculations of expenses for maintenance of way."

Construction of street-railway lines in Canada was almost stopped by the depression in 1908. For the entire year ended December 31 last there were laid a total of only thirty-three miles of track, and of this, half was built by one company, the Brantford & Hamilton line. Electric-railway building at best is being done on a very small scale in Canada, as compared with its rapid development in the United States. In the year 1907 there was laid a total of only seventy-two miles of new track. The current year promises to be somewhat better, inasmuch as one line, the British Columbia Electric Railway, has now under construction more mileage than was built by all the roads in the past two years.

Transformers

H. B. GEAR and P. F. WILLIAMS

Commonwealth Edison Co., Chicago

THE transformer is perhaps, next to the generator, the most important piece of apparatus which the electrical engineer has at his disposal. Without it the development of alternating-current transmission and distribution systems would have been so greatly restricted that the use of electricity would never have become more than a small fraction of what it

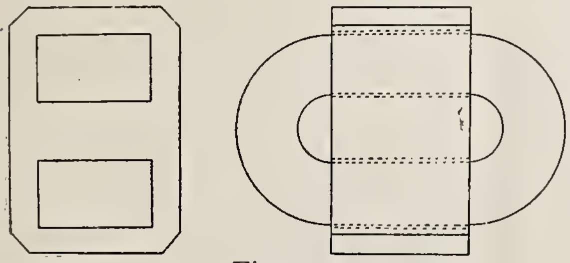


Fig. 1

is. Distribution would have been limited to lower voltages and transmission would not have passed beyond the limits within which generator and motor voltages are confined, say 15,000 to 20,000 volts.

The transformer is the simplest piece of apparatus which is employed in electrical engineering to any great extent, consisting merely of primary and secondary coils on an iron core. Its lack of moving parts makes it a mere combination of copper and iron which needs only the application of an electromotive force at its terminals to make it instantly operative.

The physical phenomena which take place in the transformer are, however, not quite so simple as its construction.

The primary coils receives electric current in sufficient quantity to magnetize the iron core. The magnetism so excited induces an electromotive force in the secondary winding which is proportional to the number of turns of wire in it. The iron core absorbs energy due to hysteresis and eddy currents which is proportional in general to the amount of iron in the core and to the frequency of the supply. The presence of the iron core makes the self-induction of the primary very high at no-load. This results in a very high counter electromotive force of self-induction which limits the no-load current to a small percentage of the full-load carrying capacity of the windings. This magnetizing current is one-quarter cycle behind the impressed voltage. The iron loss draws current also which is in phase with the impressed voltage. The resultant of these two is called the leakage current, the lagging component being known as the magnetizing component, since the magnetic flux is in phase with it. The secondary induced electromotive force is a quarter cycle behind the magnetic flux and therefore a half cycle behind the primary impressed pressure, and in opposition to it.

When load is connected to the secondary, the magnetization set up in the core by the secondary current opposes that of the primary and lowers the apparent self induction of the primary. This permits enough more current to flow in the primary to make the primary ampere turns equal to the secondary ampere turns plus the amount due to the leakage current. The power factor of the primary current at full load must necessarily be practically the same as that of the secondary since the leakage current is but a few per cent. of full-load current. The magnetizing component of the leakage current is about twice the loss component in the ordinary sizes of distributing transformers above 1 kw.

There are two principal laws governing the design of the transformer.

The first of these is very simple and states that the ratio of transformation of a transformer is the ratio of the number of turns in the primary to the number in the secondary. That is, a transformer receiving energy at 2000 volts and delivering it at 200 has a ratio of 10 to 1 and has ten times as many turns in series in its primary coils as there are in series in its secondary coil. When a transformer is wound with two or more sections in its primary or secondary coils, its ratio of transformation can be changed by changing the connections from series to parallel. For instance, in a 1040-2080 to 104-208 volt transformer there are four possible combinations of connections, viz., (*a*) primary and secondary sections both in parallel 1040 to 104, or 10 to 1; (*b*) primary in parallel, secondary in series 1040 to 208, or 5 to 1; (*c*) primary in series, secondary in multiple 2080 to 104 or 20 to 1 and (*d*) primary in series, secondary in series 2080 to 208 or 10 to 1.

It is usual to make the primary winding of line transformers interchangeable so that they can be used on either 1040 or 2080-volt systems. The secondary windings of line transformers are divided so that they can be used in three-wire distribution in sizes of 1.5 kw. and upward.

Transformers designed for transmission service are frequently made with several coils on both primary and secondary to permit their being connected in series for use on higher voltages later as the system develops.

The ratio of transformation is also sometimes made adjustable by steps of 5, 10 or 15 per cent., by bringing taps out from one of the windings of the transformer by which the pressure may be raised or lowered as conditions may require. Such taps are often specified in ordering transformers which are to be used with delta connection on a three-phase transmission where it is expected to raise the transmission voltage later by a change to star connection.

The ratio of transformation expressed in terms of the ratio of the number of turns in the coils is strictly

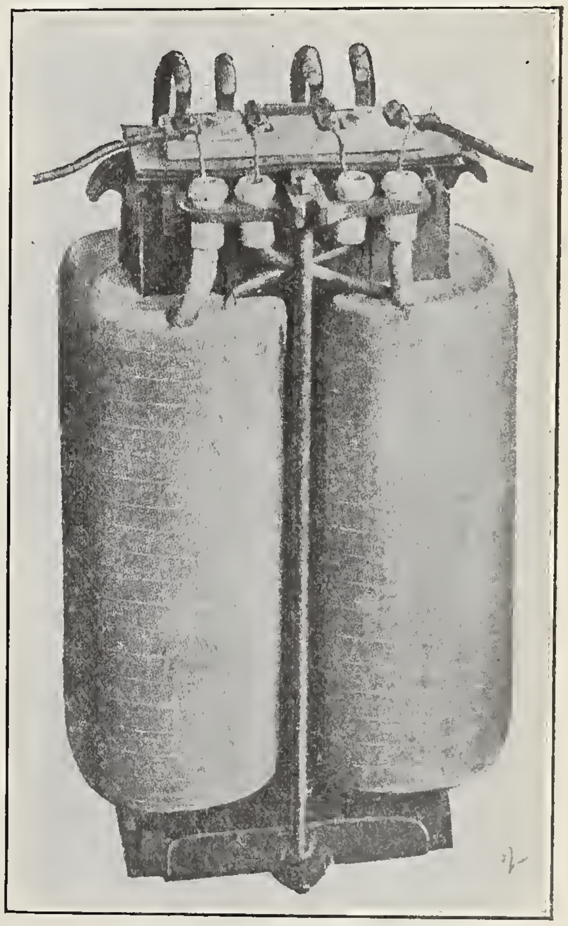


Fig. 2

true only when the transformer is carrying no load. The resistance and inductance of the windings cause a reduction in pressure of 2 per cent. to 3 per cent. when the transformer is carrying full load, thus modifying the ratio of transformation slightly.

The ratio of the number of turns in primary and secondary being fixed by the voltages of supply and delivery, it is necessary for the designer to fix

Fig. 3

the number of turns in one of the coils arbitrarily. This number must be high enough to furnish the magnetizing force for the core without requiring too much leakage current at no load. This leakage current in line transformers should not exceed 3 per cent. of normal full-load current except in the smallest sizes, as there are many of them on a distributing system. The combined leakage current in a large system having a power factor of 50 to 60 per cent. tends to interfere with the regulation of the generator pressure, and to increase the energy required for excitation of the fields, during the hours of light load.

On the other hand, an increase in the number of turns requires a greater length of wire, which in turn tends to increase the cost of the transformer and reduce its efficiency. The number of turns must, therefore, be selected so that the leakage current and length of wire will be within proper limits.

The fundamental formula by which the induced voltage of a transformer is calculated will illustrate these facts. The induced voltage of a transformer is $E = \dfrac{4.44 f \times n \times F}{100,000,000}$ in which f is the frequency in cycles per second, n the number of turns in series in the coil and F the total magnetic flux in the core, at the maximum point of the wave. For 60 cycles and 2080 volts this becomes:

$$2080 = \frac{4.44 \times 60 \times n\,F}{100,000,000}$$

or n F = 781,000,000

It is apparent that either the number of turns must be assumed to find the total flux, or the flux may be assumed to find the number of turns. The number of turns fixes the weight of copper, and the copper loss, while the magnetic flux fixes the weight of iron and the iron loss.

It may seem at first sight that the area of the cross section of the iron core would be about the same for all transformers designed for a given voltage and frequency without regard to size, since the product of the turns and the flux is a constant which is fixed by the voltage.

However, the exciting current may be made proportional to the kilowatt capacity and this permits the number of turns to be reduced in the larger units, thus increasing the amount of iron in the core. For instance, in a 2-kw. transformer designed for 2080 volts, there would be required about 1900 turns in the primary to keep the exciting current down to a proper amount. The total flux would therefore be F = 781,000,000/1900 = 411,000 lines. In a 20-kw. unit the full-load current being 10 times greater, the exciting current may be several times greater. Assuming that the primary has 600 turns, the total flux will be 781,000,000/600 = 1,300,000

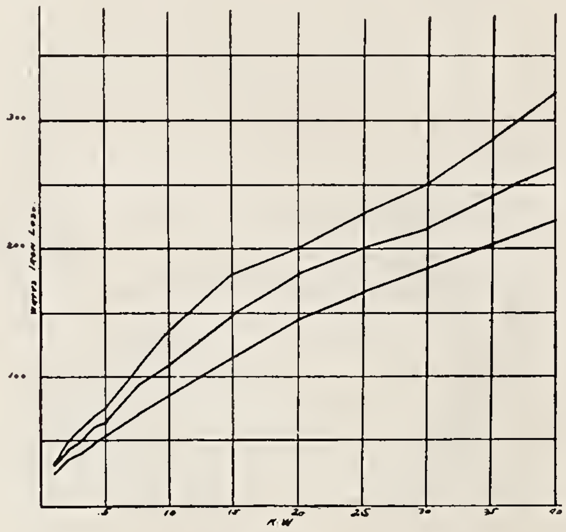


Fig. 4

lines. The average length of a turn is increased because of the greater area of the cross section and the length of wire is therefore not reduced in proportion to the reduction in the number of turns. A number of trial calculations must be made with different ratios of turns to flux, until the most economical combination is found for each size.

The total magnetic flux being determined the area of the cross section of the magnetic circuit is fixed by an arbitrary assumption of magnetic density per square inch. This value is somewhat elastic and may be adjusted within 15 or 20 per cent. of a mean value in order to produce consistent designs. The iron loss varies as the 1.6 power of the magnetic density. The law governing this is due to Steinmetz and is

$$\text{Iron loss} = \frac{K f V B^{1.6}}{10,000,000}$$

in which f is the frequency, V the volume of the iron, B the number of lines per unit of area and K a constant depending on the kind of iron used.

It is evident from this formula that if the density is increased, the core loss increases more rapidly and excessive heating results. On the other hand, if the density is greatly decreased, the weight of iron is increased and the cost goes upward.

In the smaller sizes of 60-cycle transformers where the weight of iron is small in proportion to the copper, the density is made lower so as to partly equalize this disparity. The iron in units of 1 to 5 kw. is therefore operated at from 40,000 to 45,000 lines per square inch. In the larger sizes it is made 45,000 to 50,000 and in transmission units as high as 60,000 lines per square inch.

At 25 cycles the total flux for a given voltage must be greater, and this tends to require greater cross section. The iron loss, however, falls off with the frequency and the density may be increased enough to make up for the decrease in frequency. This permits the design of 25 cycle units at densities of 60,000 to 90,000 lines per square inch. On the other hand, 125 cycle units are usually operated at 30,000 to 40,000 lines. The density having been assumed, the area of the core is

$$A = \frac{F}{B} \text{ or } \frac{1,300,000}{50,000} = 26 \text{ sq. in. in a}$$

20-kw. unit.

The magnetizing component of the leakage current for a given design may be computed from the formula $C = \dfrac{B\,L}{4.44\,N\,P}$ in which B is the number of lines of force per square inch, L the length of the magnetic circuit

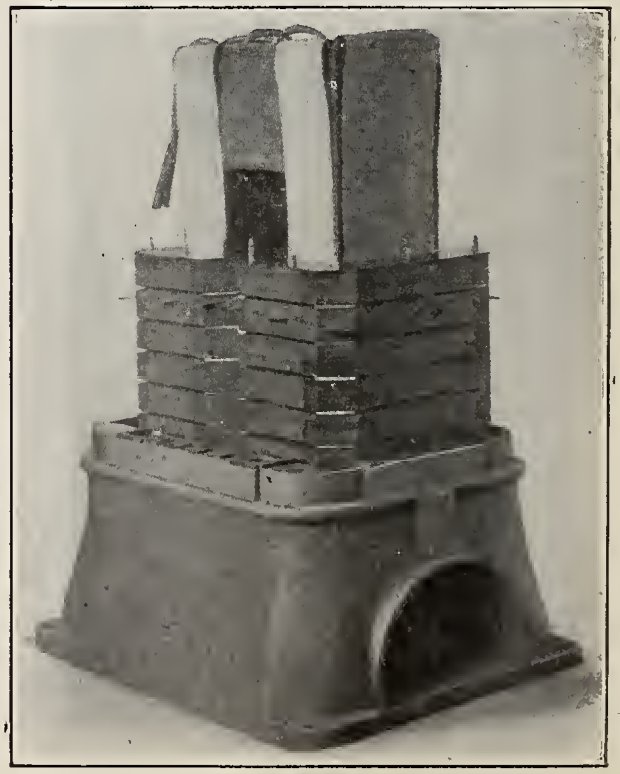


Fig. 5

in inches, N the number of turns and P the permeability of the iron. Assuming a magnetic density of 50,000 lines per square inch and a permeability of 2000, the magnetizing component of the leakage current would be

$$C = \frac{50{,}000 \times 1}{4.44 \times 200 \times N} = \frac{5.63\ L}{N}$$ or assuming the magnetizing current, the number of turns is $N = \frac{5.63\ L}{c}$

The number of turns and total flux of various sizes of distribution transformers are approximately as given in the following table:

K. W. Cap.	1	2	3	5	7.5	10	15	20	25	30	40	50
Mega lines........	.26	.411	.550	.700	.88	1.02	1.2	1.35	1.45	1.53	1.7	1.85
Turns............	3000	1900	1420	1100	890	780	650	580	550	510	460	420
Area of core, sq. in.	6.5	9.5	12.2	15.5	17.6	21	23.5	26	27	28	31	34

The formula $E = \frac{4.44\ n\ f\ F}{100{,}000{,}000}$ has been applied numerically in the foregoing only to units designed for 2080 volts and 60 cycles. It is apparent that for higher voltages the product n F will be proportionately higher and that more iron and copper will be required to construct a transformer of given capacity as the voltage is increased. Likewise, if the frequency is lower the product n F is proportionately higher and more copper and iron is required to construct a transformer of given type and size in direct proportion. On this account 25-cycle transformers and induction motors require more material than the similar types of 60-cycle apparatus and cost more to build.

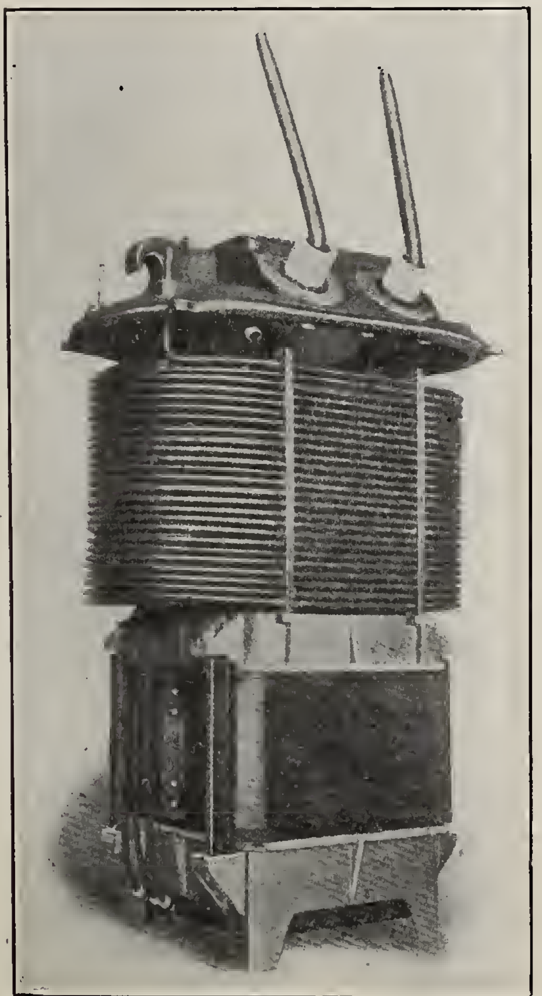


Fig. 6

There are two general types of windings and core used in transformers. One is known as the shell type, the other as the core type.

In the shell type the coils are threaded through the magnetic circuit and are surrounded by it, while in the core type the coils surround the core. The usual form taken by the shell type is that shown in Fig. 1. It has been used to some extent in line transformers and very generally in connection with synchronous converters where forced air cooling is employed. The core type shown in Fig. 2 has been used very generally for line and transmission purposes where oil cooking is relied upon. The cylindrical form of the coils lends itself to dissipation of heat and the application of insulation more readily than the flat type of coil used in the shell type. The core type has therefore been used very generally for distribution purposes.

In recent years a modification of the shell type shown in Fig. 3, known as the cruciform type, has been developed, which permits the retention of the cylindrical form of coil with the shell type of core. This form which has been adopted by the two largest American manufacturers, reduces magnetic leakage to a minimum, improves regulation and makes a very compact and efficient arrangement of copper and iron.

In the construction of the magnetic circuit of the transformer, the iron must be in sheet form to reduce the flow of eddy currents which tend to be set up by the alternating magnetic flux. The sheet iron is commonly about .012 inch thick, this thickness having been found to be the most effective and economical. The shape of the stampings of sheet metal is carefully worked out so that they may be built up around the form-wound and insulated coils with facility. This must be done so as to affect the reluctance of the magnetic circuit as little as possible. The alternate laminations are therefore usually overlapped so that the magnetic lines of force do not have to cross a butt joint. The laminations are secured in position by bolts holding them rigidly in place.

The art of manufacturing sheet iron for use in making laminated magnetic circuits for alternating-current apparatus has made progress steadily from the beginning of the industry. In the early years of alternating-current development the electrical manufacturer had nothing at his disposal in the way of sheet iron except the standard grades turned out for general purposes. It was found very soon that such iron when used in a transformer had magnetic properties which were variable with the length of time in service. The hysteresis loss per pound was high because of lack of proper annealing and varied widely in different lots because of the lack of uniformity in the heat treatment in the mill. The result was that a transformer which was reasonably efficient at the date of manufacture passed through a process of aging which left it with a greatly increased hysteresis loss and reduced its all-day efficiency very materially. As soon as this phe-

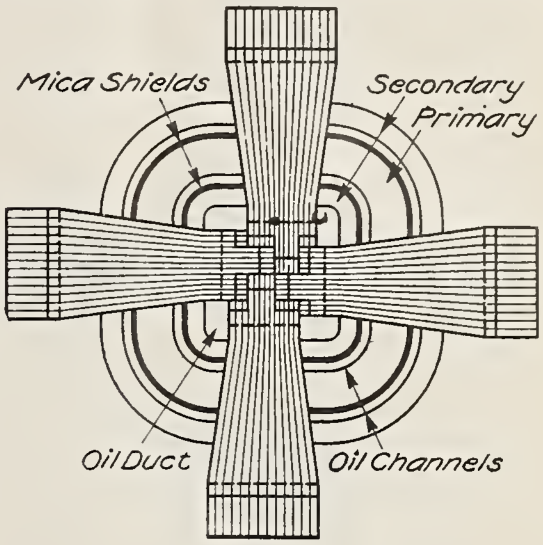


Fig. 7

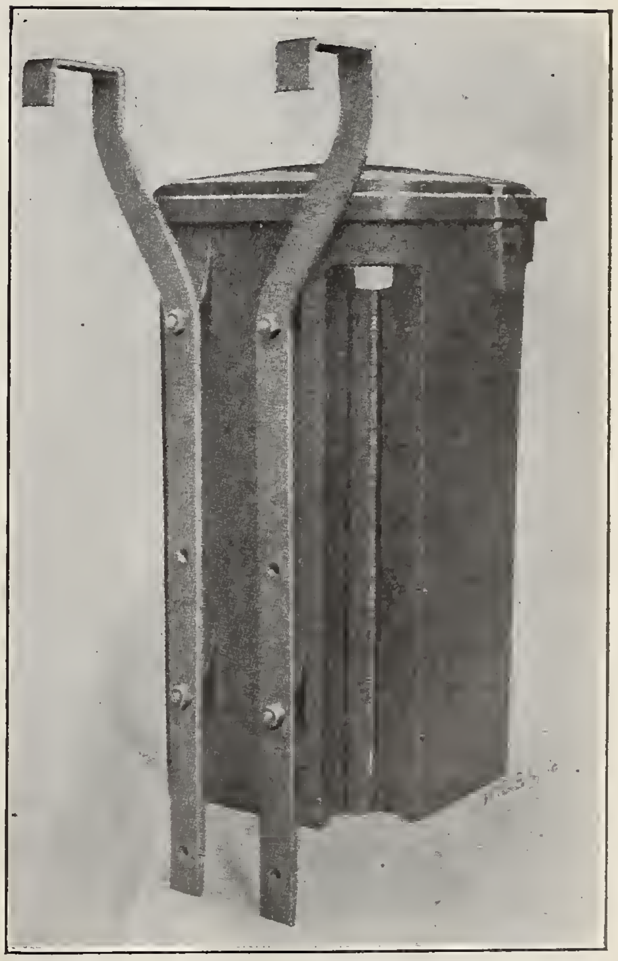


Fig. 8

nomenon became well established, an endeavor was made to establish the cause of the ageing. The continued operation of the iron at higher temperatures than normal atmospheric seemed to be the seat of the trouble

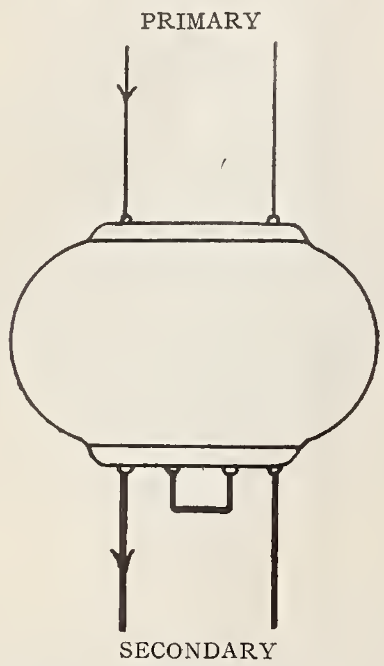


Fig. 9

and experiments were therefore directed along the line of careful control of the heat treatment of the sheet metal during the process of manufacture to insure as perfect annealing as possible in the finished product. The accumulated experience of several years produced gradual improvement in the magnetic properties of sheet iron, though ageing has not been entirely eliminated.

However, in recent years experiments in the manufacture of sheet metal from an iron and silicon alloy have reached a stage which is very promising, and transformers are being manufactured with cores made of this metal, which not only permits the use of less core material, but reduces the core loss and practically eliminates the ageing effect. Manufacturers of transformers have been able to change their transformer designs, reducing the cost of construction and producing more efficient apparatus.

The progress which has been made during the years 1898 to 1909 is made very plain by the curves in Fig. 4, which show the iron losses in the various sizes of line transformers at three points during this period.

The copper losses of the transformer assist in the production of heat while it is carrying load, and they must therefore be so limited as to keep the temperature of the interior of the transformer from rising more than 45 to 50 degrees cent. above the surrounding air.

The elevation of temperature is determined by the radiation factor and by the energy losses. In an air-blast transformer, for instance, the energy loss per kilowatt of capacity is considerably higher than in an oil-cooled unit because special facilities are provided for carrying off the heat generated.

The selection of cross sections of copper for the windings is therefore fixed within certain limits by the heat losses therein.

In the small sizes the large number of turns and the very small current in the primary coil favor the use of a lower current density than is permissible in the larger sizes. Except in the sizes less than 5 kw. the copper is run at from 400 to 500 cir. mils per ampere at full load. These densities give copper losses which are somewhat greater at full load than the iron losses in the smaller sizes and running up to about twice the iron loss in the larger units.

The copper must be ample to keep the regulation of the transformer within proper limits. Where regulation is not important, the copper losses may be increased somewhat.

The regulation of the transformer is the drop in pressure due to the resistance and inductance of its windings. It is, therefore, variable with different power factors. The impedance drop of a transformer is that pressure which is required at the terminals of the primary to drive full-load current through the transformer with its secondary short-circuited.

The resistance drop may be determined by passing direct current through the windings. This being known, the reactance drop is $X = \sqrt{Z^2 - R^2}$. The resistance and reactance drops being known, the regulation of

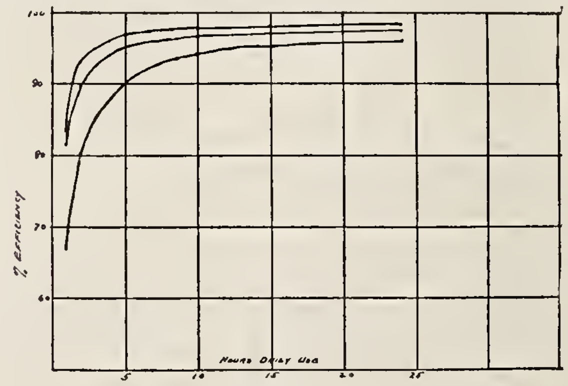


Fig. 10

the transformer when carrying load at any power factor may readily be determined by reference to a Mershon diagram, the resistance and reactance drops being treated as if they were the ohmic and inductive drops of a feeder carrying a load at the given power factor.

The problem of disposing of the heat generated in a transformer is one which has required a large amount of study and experiment. In the beginning of the art when units were small, natural radiation into the air was sufficient. As sizes increased this was inadequate to keep down interior temperatures to a point where slow char-

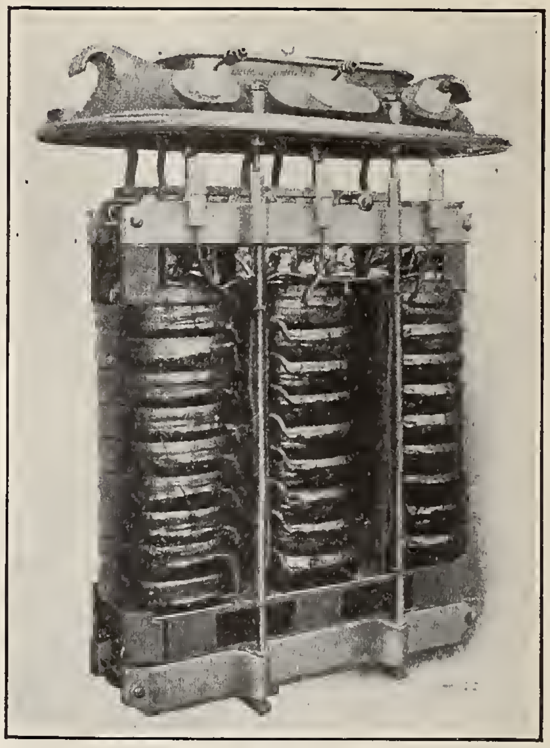


Fig. 11

ring of insulating materials would not take place. The air blast was naturally suggested as a means of hastening radiation and has found a useful field in stations and substations where attendance is continuous and floor space is limited. This type of transformer is shown in Fig. 5.

This was not feasible, of course, for distribution work and the use of a bath of oil around the coils was tried. This served the double purpose of excluding moisture and assisting radiation by the action of convection currents which cause the heated oil next to the coils to rise to the top, drawing the cool oil up from the bottom to take its place. This plan was soon found to be so effective both in cooling and insulating the coils that it became standard practice with all the principal manufacturers and continues to be the method used for all line transformers and for station work where floor space is not limited or where the voltage of transmission is very high. In the larger units, say 1000 kw. and upwards, the size of the case necessary to hold oil sufficient to radiate the energy at the proper rate becomes excessive. It is, therefore, usual to provide a case of sufficient size to contain the transformer and cooling coils of pipe as shown in Fig. 6. The transformer and cooling coils are immersed in oil which serves to convey the heat from the transformer below to the coils above. Water is circulated through the cooling coils in proper quantities to carry away the heat liberated in the transformer. This method of cooling is readily applicable where a cheap supply of water is available. It is not so economical where a supply of water must be purchased at usual water rates.

In very large units, 2500 kw. and over, it is sometimes justifiable to pro-

vide a forced circulation of water or oil to carry away the heat. In such cases it may also be necessary to provide means of cooling the circulating liquid. Such problems are, however, special and must be worked out to suit local conditions.

In the design of the coils and cores of self-cooled oil-insulated transformers, it is important that they be so shaped and mounted on the core as to permit a free circulation of oil about them. For instance, in the core type transformer the square corners may be used in conjunction with the cylin-

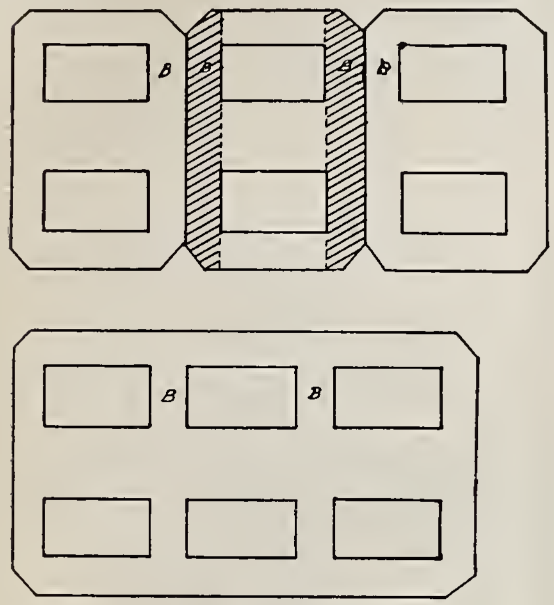


Fig. 12

drical coils to provide open vertical channels or flues through which streams of oil may pass, thus reaching the inner parts of the coils and core, and preventing these parts from reaching a temperature very much higher than the outside parts as shown in Fig. 7.

In the shell type this is not so feasible, and radiation must be accomplished by flaring apart the coils at the ends where they turn so that the oil can reach them on both sides, and by providing circulation slots between the coils.

The radiation of heat from the case is facilitated by vertically corrugated surfaces which may be so designed as to greatly increase the radiating surface without increasing the cubic contents of the case.

The insulation of the coils of a transformer from each other and from the case is of supreme importance. In transmission work large amounts of power are dependent upon the reliability of the transformer, while in distribution work not only the central station service but the lives of consumers and the general public are dependent upon it to a large extent.

The conductors are double cotton covered to separate adjacent turns while the layers are separated by a proper thickness of varnished cambric, sheet mica or other insulating material. The completed coil is wrapped with linen tape covering the cotton braid, after being impregnated with heated insulating compounds which drive off any remaining traces of moisture.

The primary and secondary coils being placed in close proximity are separated from each other by mica and hard wood or fibre so as to provide an oil-filled gap between the coils. The coils are likewise separated from the core by sheets of mica and other material. The cylindrical type of coils used in core type construction and in the improved shell type are easily protected by layers of mica and are therefore the most reliable form of coil for distribution purposes. Forms which require the protection of sharp corners are more difficult to insulate safely. Mica is not affected by heat or moisture and therefore forms the best insulating material where it can be applied effectively in sheets.

Distribution transformers are commonly provided with rugged cast-iron cases adapted to stand exposure to the weather and to the rough handling incident to installation and removal at occasional intervals. They must be oil-tight, as leakage is likely to result in claims for damages from property owners as well as very unsightly equipment. The cover is made removable for convenience in filling with oil, and in changing the primary coil connections from series to multiple. Lugs are cast on the case to fit wrought-iron hangers by which they may be conveniently hung on a cross-arm, as shown in Fig. 8.

It is customary in bringing out the leads of distribution transformers to follow a uniform method of connecting up coils on primary and secondary sides so that units may be coupled in parallel by following a symmetrical plan of connections without testing out for polarity every time. The polarity is made such that current is leaving the right-hand terminal of the secondary at the same time that it is entering the transformer through the corresponding terminal of the primary, as shown in Fig. 9.

The physical laws governing the magnetic characteristics of a transformer having an iron core are fortunately such that the relative amount of copper required is small, and the losses in the copper windings are not as great as they are in a generator or synchronous converter. The lack of moving parts further tends to make the transformer the most efficient piece of electrical apparatus which is in general use.

The efficiency of a transformer which is used in transmission work is of most importance at the time of full load, since it usually carries its load eight to ten hours or more per day, and its iron losses are a small part of its converted output. It is important, therefore, that its copper losses be low, and its full-load efficiency as high as possible. In a distribution transformer supplying lighting load four to five hours per day, the full-load efficiency is less important while the iron loss which goes on 24 hr. may become a considerable percentage of the daily output of the unit.

For instance, in the case of a 5-kw. transformer which delivers 20 kw-hr. per day, the copper loss would be about 100 watts at full load, while the iron loss would be about 50. The copper loss per day would be about 400 watt-hr. while the iron loss would be 24x50 =1200 watt-hr. The total loss being 1600 watt-hr., the all-day efficiency is

$$\frac{20}{21.6} = 92.6 \text{ per cent.,}$$

while that at full load is

$$\frac{5000}{5150} = 97.1 \text{ per cent.}$$

It is apparent that the all-day efficiency varies with the load factor or hours' use of the maximum load. The efficiency at various load factors is shown for several sizes of transformers in the curves in Fig. 10. It is evident from these curves that a system in which there are a considerable number of 1-kw. transformers will have a lower all-day efficiency than one in which the same amount of load is supplied

K. V. A.	Watts Loss		Per Cent. Efficiency Full Load	Per Cent. Regulation		Per Cent. Exciting Current
	Core	Copper		100 per cent. P. F.	80 per cent. P. F.	
1	20	24	95.8	2.42	3.12	5.5
1½	25	34	96.2	2.28	3.01	4.0
2	30	42	96.5	2.12	2.88	3.6
3	34	64	96.8	2.16	2.91	3.0
4	40	75	97.2	1.90	3.00	2.5
5	45	93	97.3	1.90	2.99	2.3
7½	62	125	97.6	1.70	2.84	2.2
10	80	148	97.8	1.51	2.68	1.9
15	105	212	97.9	1.44	2.63	1.6
20	131	268	98.0	1.39	2.87	1.5
25	147	319	98.2	1.33	2.82	1.3
30	163	374	98.2	1.32	2.82	1.2
40	205	433	98.3	1.20	2.72	1.2
50	240	550	98.4	1.15	2.68	1.0

TABLE SHOWING EFFICIENCY, COPPER LOSS, IRON LOSS AND REGULATION.

by 5-kw. transformers. The average size of transformers should, therefore, be kept as large as is consistent with a reasonable investment in secondary mains.

The efficiency, copper loss, iron loss and regulation of the distribution transformers of the improved shell type made by the leading American manufacturers are shown in the table on page 87.

The copper loss and regulation figures in the above table are based on a temperature of 77° fahr., whereas, under the normal condition of full-load operation, the temperature of the windings is about 150° fahr. The increase in the resistance of copper being about—0.22 per cent. per degree fahr. of rise, the increase in resistance at 150° would be $73 \times 0.22 = 16$ per cent. The copper losses at 150° would therefore be about 16 per cent. higher than the values shown in the above table and the regulation would be proportionately increased. In a 5-kw. transformer the copper loss would be $93 \times 1.16 = 108$ watts, while the regulation at 100 per cent. P. F. would be $1.9 \times 1.16 = 2.2$ per cent.

In three-phase systems the possibility of saving a part of the core material and reducing the cubic feet occupied has led to the adoption of three-phase units in some kinds of work. The three-phase unit as worked out in the shell type with air-blast cooling effects a saving in floor space and in first cost which has made it standard for synchronous converter work. In the core type unit illustrated in Fig. 11, the cooling is effected by oil and this type is used in distribution work or in situations where attendance is not continuous. It is not usual to attempt to use a three-phase unit smaller than 15 kw. Having the three phases contained in one case they are made in larger capacities than single-phase units, having been made as large as 7500 kw. for use in transmission work.

For general distribution purposes, the three-phase unit in sizes less than 150 kw. has some serious limitations. It puts the entire load furnished by the unit out of service if any trouble develops in either phase of the unit, and the expense of providing a substitute unit is necessarily greater.

Where transformers of all sizes must be kept on hand to take care of light and power service, it is far more flexible to have single-phase units which are available for either light or power than to attempt to carry a line of single-phase units for lighting and three-phase units for power.

In construction work where the transformers are hung on poles, it is easier to distribute the weight of the transformers on the pole with three units than with one in installations of 50 kw. or more. In underground work the saving in space is of value in a manhole, but the shape of the three-phase unit is such that it cannot be installed or removed unless a special size of manhole cover is used.

The three-phase unit has therefore not been generally used in distribution work.

In the design of the core of three-phase units, some saving in the weight of core metal is possible when the middle phase is connected in reversed order so that the magnetic fluxes of the adjacent phases do not combine in the usual 120° relation, but at 60° apart.

For instance, the shell type unit, as shown in Fig. 12, may be designed with the same cross-section at B as each of the three single-phase units has at the points B, thus saving the shaded portion of the middle single-phase core.

Reinforced Concrete in Electrical Transmission Lines

ALL new inventions which are in the nature of improvements on existing ways of doing things have to pass the crucial test of competition before they can be considered as established. Possession of the field is a mighty advantage, and the burden of proof is ever on the newcomer, which if it is to make good must do so because it is the best. It is the struggle for existence, that great law of the domain of nature working equally in the region of man's endeavor.

In forming a judgment of the value of a new invention of this kind, a comparison should be made with the existing means of accomplishing the same end. This comparison will force consideration of the relative advantages and disadvantages of the new scheme as concern the three great points of technical merit, manufacturing, feasibility and economy. From this study estimates of the net practical utility of a new idea can be made with more or less accuracy which may serve as a basis for action.

The use of reinforced concrete in all its numerous branches is one of the latest inventions of the modern world and bids fair to become of vast importance. The electrical engineer and construction man have been among the foremost to seize on its possible advantages, and to-day it plays a most important part in the construction of power-houses and substations. In the link between these two and between them and the consumer, that is to say, in the transmission and distribution of power both overhead and underground, it has so far had little to do. Unreinforced concrete has been much used in ducts and duct-line foundations and manholes for underground work, but it is in the use of reinforced concrete for pole lines of all sorts that the first great improvement will be made. This, then, is a matter of possible interest and profit to everyone connected with the telephone, telegraph and overhead transmission and distribution lines.

For overhead work the new applicant finds the field already crowded. Wooden poles untreated and treated, wooden poles with concrete settings or sockets, wooden poles with steel sockets, and numerous other modifications have been tried and found more or less wanting. The next advance was the employment of steel poles. I-shaped, tee-shaped, tubular, lattice poles and poles built up of these elements are all in use, also concrete poles, solid or with wood or some other permanent core have been and are being tried.

Until a very recent time the plain wooden pole has had the most of the field. Except in certain localities that are especially unfavorable to their life, nearly all the telegraph and telephone lines of the world are carried on millions and millions of wooden poles. With the introduction of the "small and early" electric plants of the first years of the industry, the wooden pole was the thing handiest to use and has been almost universally employed with results which can hardly be called satisfactory.

But the rapid expansion of electrical uses has worked a change for the

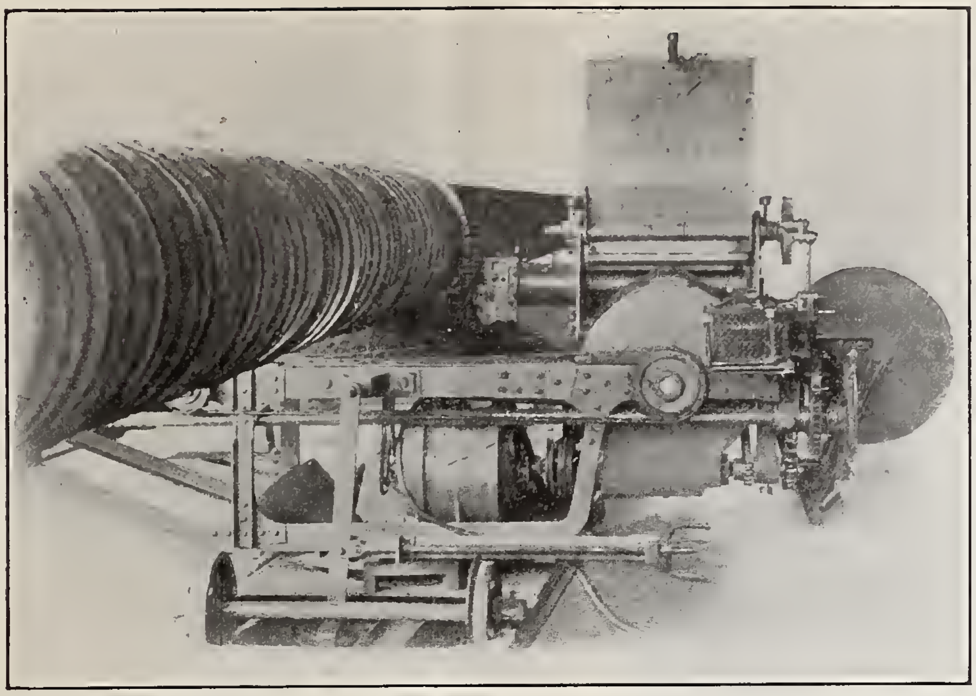


Fig. 1.—FRONT VIEW OF POLE-MAKING MACHINE.

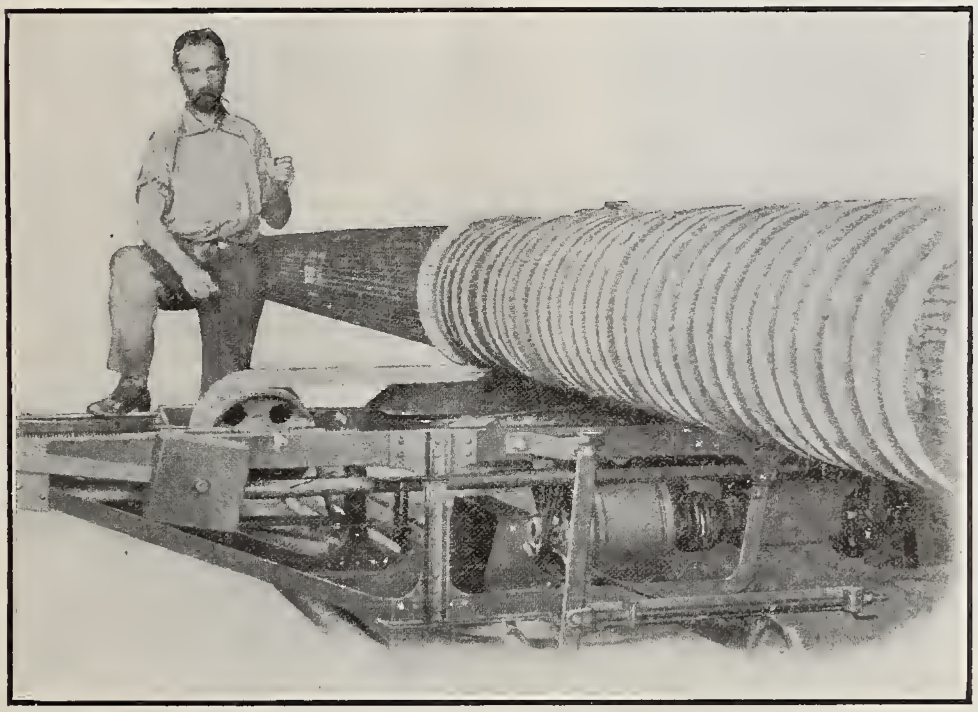


Fig. 2.—REAR VIEW OF POLE-MAKING MACHINE.

worse in the wooden pole supply. The enormously increased demand has greatly increased the price, and worse still, the quality of pole supplies is getting bad. This demand has caused poorer timber to be used, less care in sorting, and a general slacking of specification; the result of which has been that greatest defect of the wooden pole—its shortness of life. Implied in the short life of the pole is the eventually increasing weakness which results in failure in storms and other abnormal stress, with costly interruptions of service and costly renewals of defective and depreciated poles.

All this has led to a demand for something less expensive in the long run and more reliable, and resulted in the use of concrete setting of wooden poles, and later in the appearance of the steel pole.

With the concrete setting the life of the wood pole is longer but still not long, as its term of service is limited by atmospheric influences. Another great objection is the high cost of renewal, as the old foundation is not available for the new pole without a great expense. To obviate this, the concrete socket was devised, but has no bearing on the length of service, merely modifying the cost of replacement. With or without the numerous preserving schemes that have been devised, the wooden pole will have to be renewed every fifteen or twenty years, and very few even of the treated poles ever obtain the latter period.

The steel pole, which next made its appearance on the market, has many points in its favor. It has a long life if properly looked after, is tough, and in the more economical form not too heavy for convenient handling. Its great handicaps are the high first cost and the high cost of maintenance which is chiefly painting.

The improvement in the knowledge of design and processes of manufacture of reinforced concrete led at last to attempts to make poles from it which should be able to compete with the steel pole. The results of these efforts have been highly successful when properly carried out, and it is a wonder that the superiority of this type of pole has not been more widely known and utilized.

The first of these poles were made by hand and were solid. This produced a pole strong and durable but of high first cost and enormous weight. The volume of an ordinary telegraph pole is about 20 cu. ft. Such a wooden pole would weigh from 600 to 1000 lb. according to the kind of wood. A solid concrete pole of the same size will weigh two to three times as much. For economy of material and handling the hollow concrete pole was devised.

Among the first to try the hollow concrete pole was the municipal lighting department of the city of Zurich in Switzerland. In this instance steel poles of different diameter were placed vertically with one inside of the other; after the setting and fastening of the reinforcing members the concrete was tamped in.

Such poles required the most careful work to insure a uniform quantity of concrete work and hence uniform strength. Hand-mixed concrete is preferred to the machine-mixed article in this sort of work, and hand tamping is not uniformly done. The slowness, lack of uniformity and high first cost of such a hand-made pole led to the development of the up-to-date machine and machine-made hollow reinforced concrete pole, which represents the very latest advance of the art, until the coming of the mechanical pole-maker. These poles can now be turned out at a much lower cost than steel poles and can be made in larger quantities in a small time.

One of the machines which has made positive the cheapening and perfecting of the manufacture of the concrete pole is that used by the International Siegwart Company of Lucerne.

This firm has a pole-making machine whose principal features are shown in the illustrations Figs. 1 and 2.

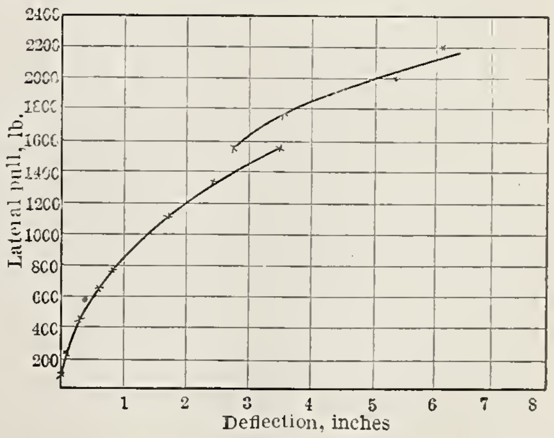


Fig. 3.—CURVES SHOWING DEFLECTION UNDER VARIOUS LOADS.

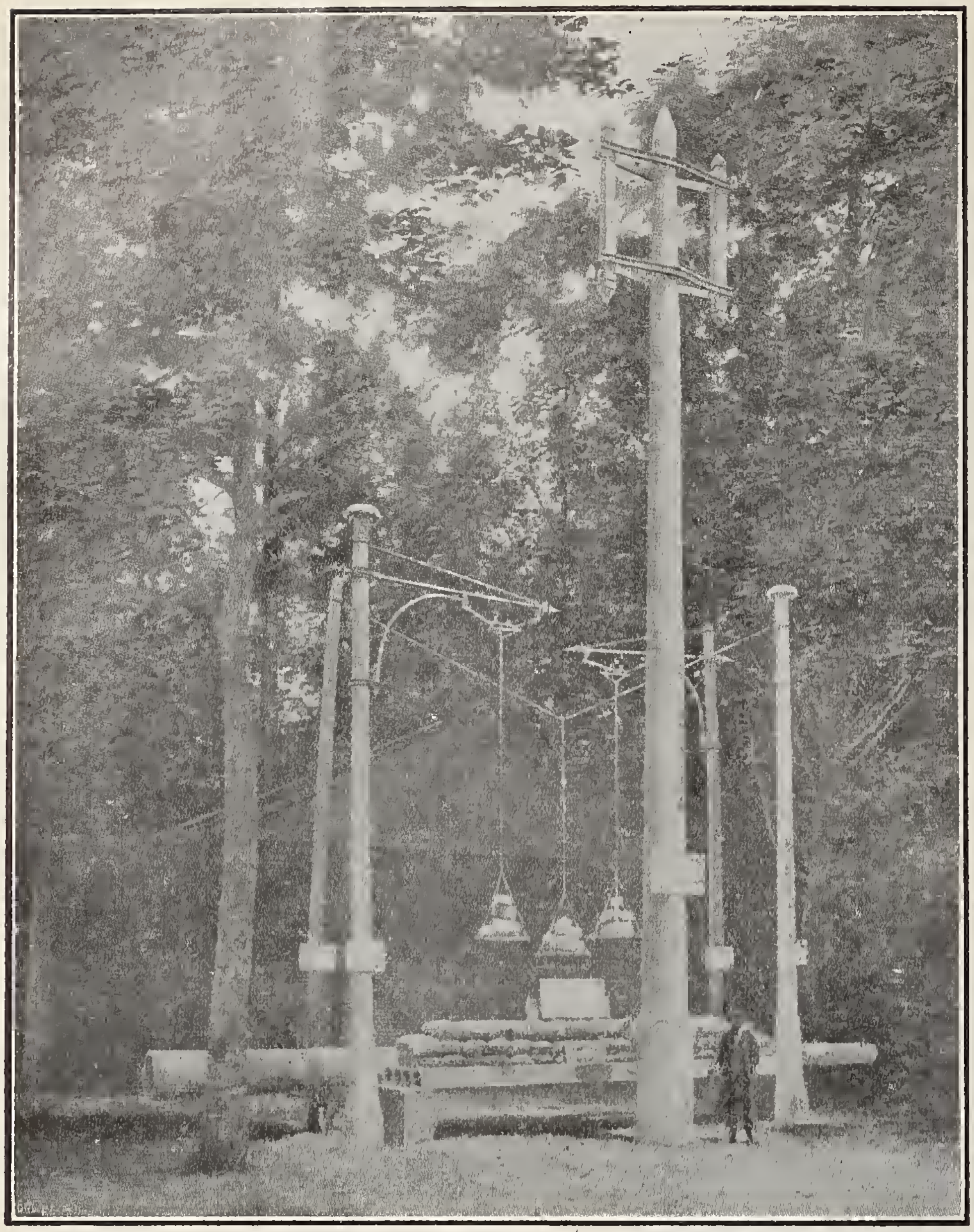


Fig. 4.—CONCRETE POLES AT THE MILAN EXPOSITION IN 1906.

A HOLLOW CONCRETE POLE-MAKING MACHINE.

An adjustable lathe-like form is arranged for mounting a hollow conical iron core mould arranged so as to be collapsible for the withdrawing after the operation. Over the outer surface of this mould the reinforcing rods are drawn symmetrically and kept taut by means of screws in the air plates. An adjustable spacing ring which slides along the mould provides for the proper location of the rods in the mass. They are carried just below the outer surface. The traveling applicator moves along the mould by a screw-driving mechanism. The applicator consists of a funnel-shaped receptacle for taking the concrete from the mixer, whose bottom is closed by a revolving drum. On the outer surface of the drum are ribs which, as the drum revolves, carry off certain definite quantities of the mixture from reservoirs, and drop them upon a carrying belt which applies them to the form as shown. The speed of the drum is adjustible and regulates the amount of mixture delivered.

The carrying belt, which applies the mixture and is the distinctive feature of the machine, is made of steel wire in order to withstand the great tension to which it is subjected. It is moved by a traveling driving pulley and another movable pulley is placed on the other side of the core mould which is caused to revolve by the pressure of the belt which makes one loop about it. Dumped by the drum on a short endless chain, the mixture is by it thrown on the upper side of the belt and by it carried around the frame and squeezed into the reinforcement by the tension of the belt which, by means of a lever-controlled tightener, can be run up over 5000 lbs.

Power for operating the entire mechanism is furnished by an electric motor which is secured under the upper frame of the machine. Screws and chain gears carry the motion to the applicator which is itself driven forward as explained above, so that the apparatus can travel the entire length of the pole.

The whole scheme of operation is well illustrated in Figs. 1 and 2. From the receptacle into which it is dumped on leaving the mixer, the concrete is carried by the drum and chain on to the belt and applied to the core as spiral strips like the threads of a huge screw, laid on close together. As the core is revolved by the belt, a pair of smoothing rollers press against the mass and completes the packing or tamping action, leaving a smooth surface. Just before the belt reaches any part, a set of spiral cross-reinforcing wires are wound off of a traveling spool, and just after the smoothing rollers have passed, a canvas strip is wound about the surface. This strip serves to bind the wet mixture in place and also helps to retain the moisture in setting. After the setting is sufficiently advanced, it is removed and can be used over again.

In this machine the process of forming a pole is quite rapid, and as soon as the screw has reached the far end, the pole with its core and canvas wrapping is removed to the setting yard. A new core is mounted in the machine and another pole turned out.

The great advantage of the machine is its flexibility. By it a hollow pole of any desired length, diameter, thickness of wall, and degree of coning or taper, within certain limits can be turned out. It is just as useful for making reinforced concrete tubes or pipe as for poles, and it is claimed that such pipe is in satisfactory use for water pressure up to 300 lbs.

The poles so turned out have the advantages of being equally and thoroughly packed and tamped, and have a form and walls that are mathematically true. Their cost, as compared to a hand-made pole, is enormously reduced.

For the production of an ideal pole of reasonable cost the following conditions are requisite:

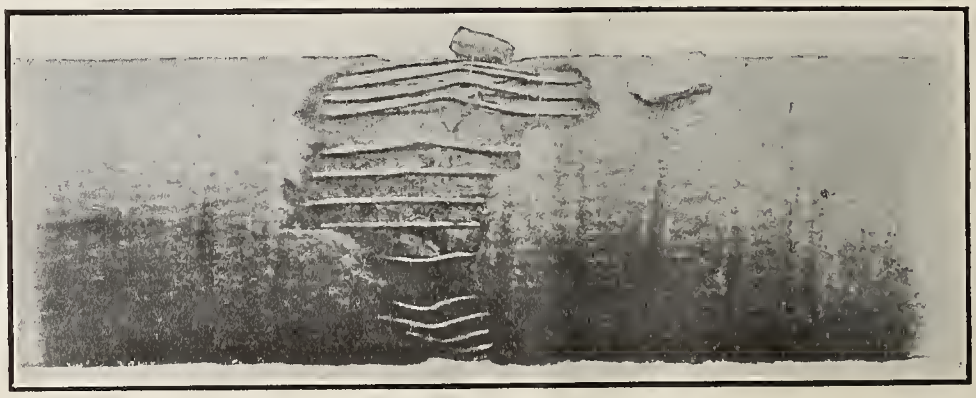


Fig. 5.—SHOWING FAILURE ON TEST.

Material capable of resisting the effects of moisture, acids and atmospheric deterioration. This means no

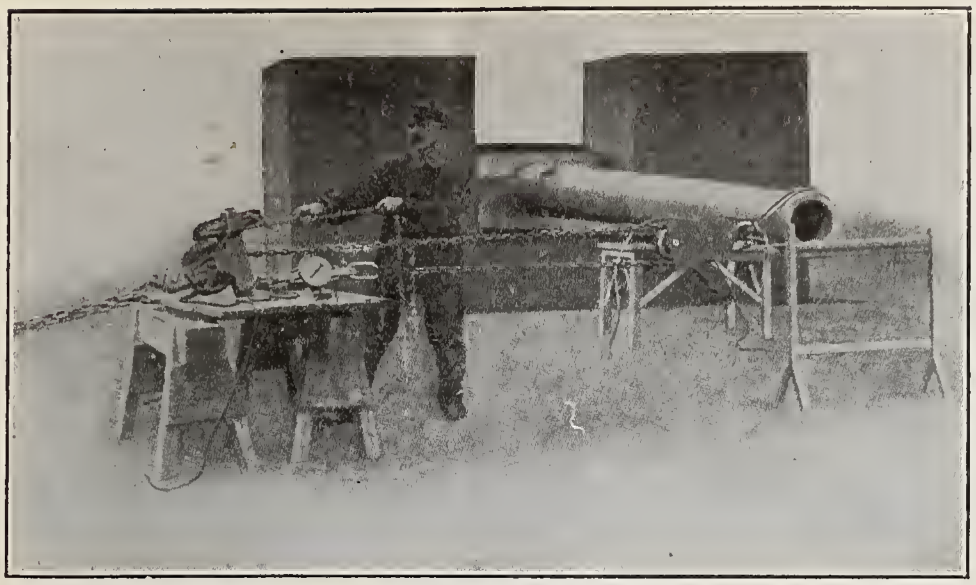


Fig. 6.—METHOD OF TESTING POLES.

labor and material for upkeep excepting in the case of violence or unusual accident. The material should be cheap and easy to prepare and apply in large quantities by machinery. The reinforcement should be placed as near the outer surface as possible without its ever becoming exposed. And last but not least, the pole should be well proportioned and have a neat and graceful appearance.

The hollow poles that have been made abroad have met these requirements. The remarkable degree of strength as shown in the bending tests given below is due to the excellence of the cement and other materials used, as well as the liberal use of high quality reinforcing rods. The cheapness is shown by the tables which give a lower cost for them than for steel poles of an equal strength. As for the matter of appearance—which however slighted in the United States, is of prime importance in Europe, especially in the cities—the poles are fully comparable with ornamental steel poles. Indeed, with this machine it is possible to give a pole that magic entasis which makes in some way thecharm of a columnular figure and whose absence or presence on such a figure makes a large part of the difference between a thing of beauty and a common eyesore.

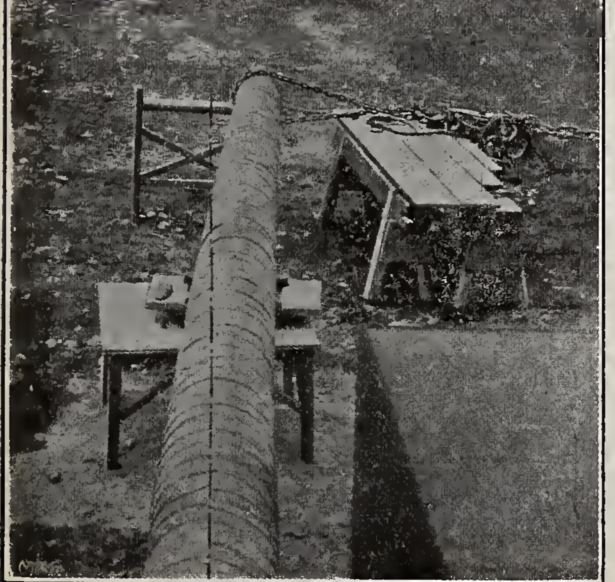


Fig. 7.—ANOTHER VIEW OF POLE UNDER TEST.

TESTS OF THE HOLLOW CONCRETE POLE

In some tests at the Milan Exposition, 1906, an ordinary wooden pole and a hollow reinforced-concrete pole were tied together at the top and a weight of 265 lb. was attached at the middle of the connecting cord, as shown in Fig. 4. Also the same weights were suspended from brackets. In the first case, under the equal strain the concrete pole was deflected 0.079 of an inch, and the wooden pole 1.18 in. In the second case, the concrete pole was not deflected at all, while the wooden pole bent 0.83 of an inch.

Following is the result of some tests of reinforced-concrete poles made in Switzerland by the Siegwart Company:

Data:

Total length of pole	23.8 feet
Diameter at the butt	16.8 inches
Diameter at the top	10.6 inches
Length of lever arm	19.6 feet
Thickness of wall	11.18 inches
Number of reinforcing rods . . .	33
Diameter of reinforcing rods . . .	275 inches
Safe horizontal pull at top . . .	520 pounds

Result:

Failure occurred at 2200 lb., the cause being the crushing of the concrete and a flaw in the reinforcement. This gives a factor of safety of a little more than 4.

For an angle pole on a Swiss transmission line the following bending test was made:

Data:

Number of wires on pole . . .	8
Diameter of wires . . . . (Between No. 0 and No. 1 B. & S.)	.316 inch
Total side pull due to 8 wires .	1300 lbs.
Length of pole	39.2 feet
Length of lever arm . . . . . (Measured from centre of tension due to wires, to the ground line)	31.1 feet
Calculated moment due to side pull	40,430 foot-lbs.
Calculated maximum wind pressure	685 lbs.
Calculated lever arm of wind pressure	13.7 feet
Calculated moment due to wind pressure	9385 foot-lbs.
Total combined pull at centres of application . . . . (*i. e.* at 31.1 feet above the ground)	1650 lbs.

The pole is fastened between two massive blocks of concrete as shown at Fig. 6. The bending force is applied by means of a chain block, the strain being measured by a dynamometer, and the deflection by a scale at the end of the pole.

Results:

I		II		III	
Pull	Deflection	Pull	Deflcction	Pull	De flection
88	0	88	0	1540	2.79
220	.118			1760	3.54
440	.314			1980	5.33
660	.592			.2220	6.1
280	.9				
1100	1.70				
1320	2.44				
1540	3.46	1340	2.75		

The diagram of this test is plotted in Fig. 3.

The discrepancy between the first and second tests in the deflection obtained with 1540 lb. pull is due to the crushing of the cement at the corner of the support. Allowing for the sinking in, the amount of net deflection was actually 2.48 instead of 3.46 in.

On releasing, the poles showed no permanent set, and on reapplying the strain the deflection was 2.75 in., as shown.

In the last part of the third test, the material of the blocks crushed again and the net deflection under 2220 lb. was only 4.72 in. instead of the 6.1 indicated in the table; the pole after this test, showed no crook or deformation of any sort and was pronounced satisfactory by the power company's engineer.

Another type of heavy pole made in two pieces for angle in transmission line is shown in Fig. 8.

Fig. 9 shows the method of erecting a two-part concrete pole. In this pole the total length assembled is 52.8 ft., the lower part being 16.4 ft. long and 27.5 in. in outside diameter, and the upper part 39.3 ft. long, with a diameter at the butt of 23.6 in., and 11 in. at the top. The overlap is approximately 2 ft. and the length below the ground line a little more than 6½ ft. The pole thus stands a little over 46 ft. high. The joint between the two sections is filled in with cement, and the lower part is filled with concrete as shown in Fig. 12. This pole is an example of the most massive and durable line construction imaginable, and standing without guys at an angle in the line of nearly 45 degrees. It supports the combined pull of six conductors; three of 0.275 in. diameter, *i.e.*, about No. 1 B. & S., one about equal to No. 4; and two about No. 2. Under the total tension of these wires the combined unbalanced side pull, without allowing for wind-pressure, amounts to 2400 lb. The deflection at the top is but 3.5 in. It is, of course,

Fig. 8.—ANGLE POLE IN A SWISS TRANSMISSION LINE.

provided with a solid concrete foundation, similar to that shown in Fig. 12.

A COMPARISON.

In summing up the advantages and disadvantages of the various kinds of poles, we have the following characteristics:

Untreated Wooden Poles: Relatively low but constantly increasing first cost, short life, high maintenance.

Treated Wooden Poles: Higher and increasing first cost, somewhat longer life; higher maintenance.

Wooden Poles with Concrete Setting: High first cost, short life, expensive to replace.

Wooden Poles with Concrete Sockets: High first cost but longer life, though still relatively short; cheaper to replace than preceding.

Steel Poles, whether latticed, hollow, or built-up, are of high first cost, long life if properly cared for, but costly to maintain.

Reinforced-Concrete Poles: With wooden cores, high first cost and life doubtful.

Hollow Reinforced-Concrete: First cost higher than wooden poles, but less than iron; unlimited life if of good material and properly made, no maintenance cost, flexible in manufacture; of any length, diameter or thickness of wall according to demands; disadvantages are greater weight and greater difficulty and cost of handling.

In order to make a close comparison of the effect of various factors in the total result, estimates are given it

Fig. 9.—ERECTING A TWO-PART POLE.

Fig. 10.—CONCRETE POLES ON A FLAT CAR.

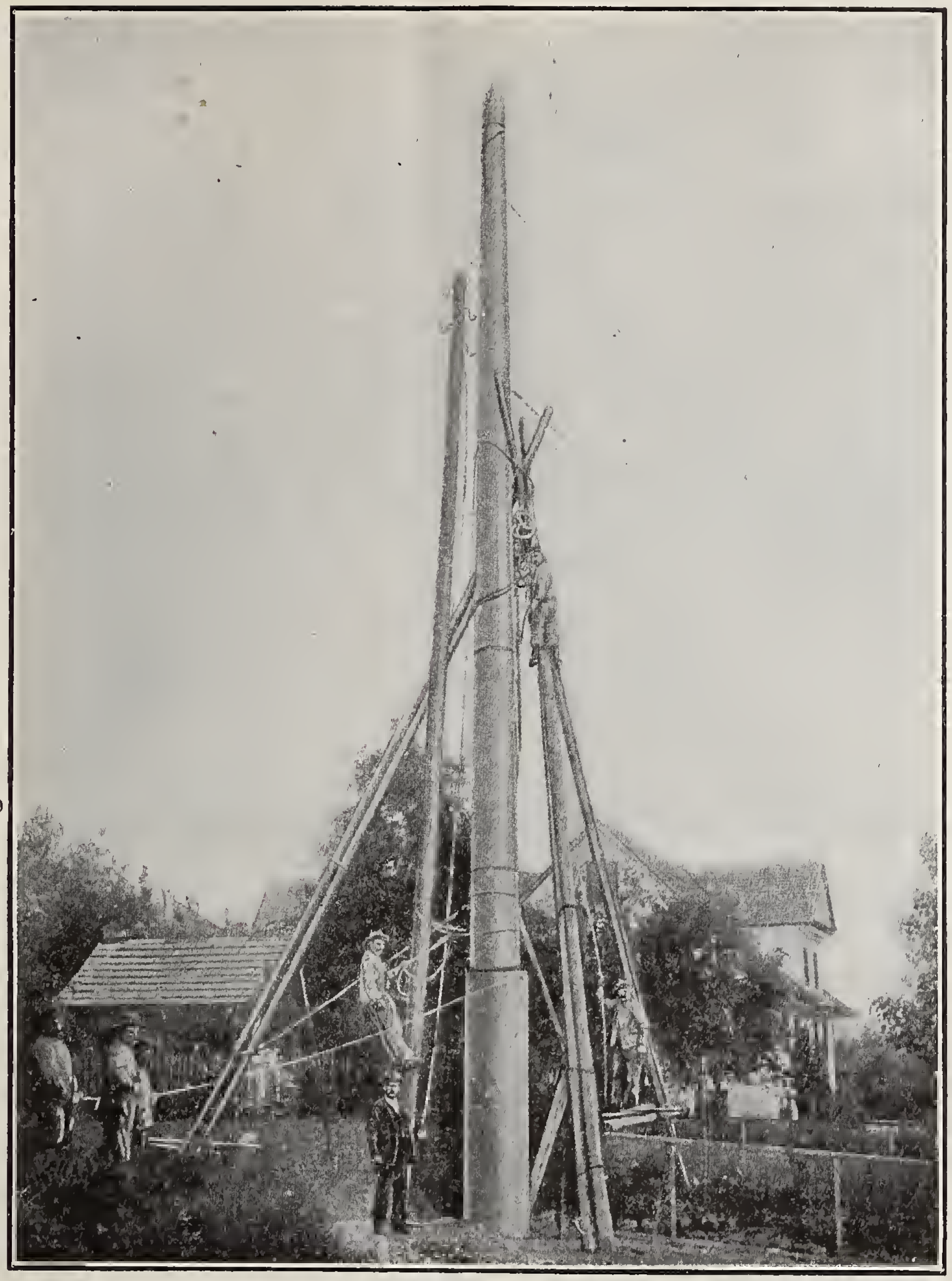


Fig. 11.—A TWO-PART POLE ERECTED.

the table below covering treated wooden poles with ordinary setting, hollow steel poles, set in concrete, and hollow concrete poles. These estimates are based on cost for material and labor prevalent in central Europe.

Straight-line poles can be made with a lower factor of safety equal to that of an ordinary wooden pole for a cost of about 15 per cent. less than the poles listed above. In this connection it must be remembered that the strength of the concrete pole increases rapidly at first and slowly for a long period thereafter, while that of the wooden pole diminishes slowly at first and rapidly toward the latter part of its life. With this fact in mind, a basis of equal strength for comparison is safer than would appear at first sight.

Comparing the above figures, it will be seen that in the case of telephone and telegraph poles at the end of 50 years, the wooden-pole line has cost over four times as much as the concrete-pole line. In fact, the cost of the wooden-pole line may be considered to have overtaken that of the concrete-pole line after the first renewal, or in less than 15 years.

In the case of the light trolley poles of the kind ordinarily used on electric railways in this country, the difference in favor of the concrete pole as compared with the wooden, is nearly $15

TOTAL COST OF POLES IN FIFTY-YEAR PERIOD

Material	Wooden Poles			Hollow Steel Poles for 1200 lbs. tension		Hollow Concrete Poles for 1200 lbs. tension factor of Safety.		
Style	Transmission	Light Trolley	Telegraph & Telephone	Transmission	Light Trolley	Transmission	Single Trolley	Telegraph or Telephone
Total length feet	36.8	28.8	29.5	36.8	28.80	36.8	28.8	29.5
First cost of pole	$4.80	$3.60	$3.60	$45.50	$32.00	$30.00	$20.00	$7.00
Cost of erecting	2.40	2.40	2.40	6.00	5.00	6.00	5.00	4.00
Painting steel poles				.80	.60			
Total cost erected	$7.20	$6.00	$6.00	$52.30	$37.60	$36.00	$25.00	$11.00
Estimated life of pole	15	15	15					
Number of renewals	3⅓	3⅓	3⅓					
Material	$4.80	$3.60	$3.60	$0.60	$0.50			
Re-erection	3.60	3.00	3.00					
Removing & replacing wires	1.40	1.00	.40					
*Miscellaneous	2.40	1.80	1.40					
Total cost of one renewal	$12.20	$9.40	$8.40	$0.60	$0.50			
Total cost of all renewals	$40.66	$30.33	$27.56	$9.60	$8.00			
Grand Total Cost	$47.86	$39.73	$33.56	$61.90	$45.00	$36.00	$25.00	$11.00

* Includes storage, distribution, extra expense, charge for overtime, night and Sunday work and loss of income from interruption to service.

In this table the double factor of safety used in the concrete pole division means poles whose strength is equal to that of the wooden poles of the sort listed. One such pole replaces the two wooden poles often used at angles.

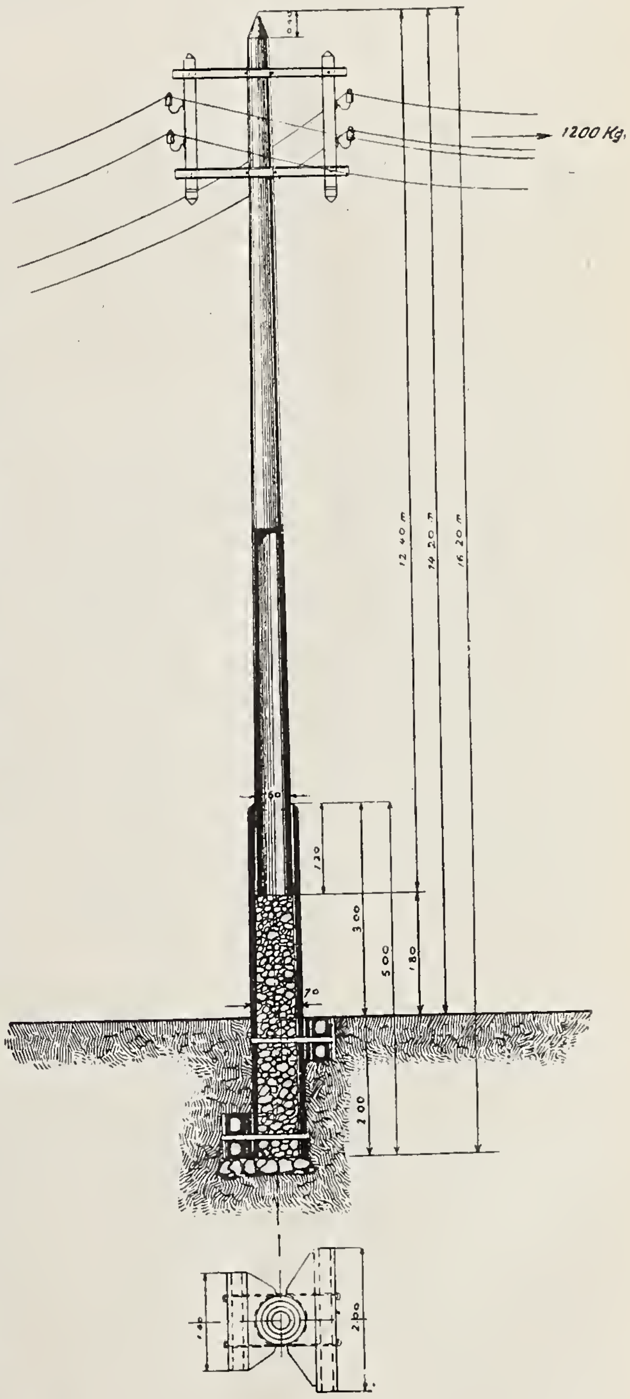


Fig. 12.—FOUNDATION SECTION OF A TWO-PART POLE.

or 60 per cent. per pole, while as compared with the steel pole, the remainder in favor of the concrete pole is $20 or 80 per cent.

The concrete pole is cheaper than the steel pole from the start; and becomes cheaper than the wooden pole after the second renewal or, say, 30 years, as the above estimates of the life of an untreated wooden pole are very liberal. The actual facts are probably even more favorable to the concrete pole than shown here.

In comparing the figures for long poles for transmission purpose, the fact that high-tension transmission lines are more and more coming to be carried on steel towers may be left aside, and comparison should be made between the type of pole as used by the tens of thousands for the distribution of electric light and power.

In this case the concrete pole is again cheaper than the steel pole from the very start, and by a large percentage, while it becomes cheaper than the wooden pole only after the third renewal.

Summing up the financial aspect of the matter as shown from the above data, we have the following:

COST AND SINKING FUND COMPARISON.

Material	Wooden Poles			Steel Poles		Concrete Poles		
Style	Transmission	Trolley	Telegraph & Telephone	Transmission	Trolley	Transmission	Trolley	Telegraph & Telephone
Total cost in 50 years...	$47.86	$39.73	$33.56	$61.90	$45.00	$36.00	$25.00	$11.00
Necessary Sinking Fund...	$0.96	$0.80	$0.67	$1.24	$0.90	$0.72	$0.50	$0.22

The Plant Owner's and the Operating Engineer's Problem

J. C. JURGENSEN

THE plant owner and the men in charge of isolated plants, and also those young men who some day hope to be entrusted with the care of a power plant, are, by many very plain signs, confronted by a problem, the solution of which cannot be avoided if the operating engineer wishes to continue the existence of his calling.

In the term operating engineer is included all those who are working and striving to become members of the vocation, because the operating engineer's cause is one and identical with that of those men, and should be regarded as such by all.

It is a problem which has its exact counterpart in many other callings the whole country over, and it must be studied and attacked not only by the single-handed endeavor of the individual and thoughtful operating engineer, but it needs the close attenten of the plant owner as well.

The individual endeavor of the engineer is no doubt of great value in that particular isolated instance where it is practised, but solving a question like this, which is only one of the many evidences of an important and far-reaching industrial problem before this country, makes it an imperative duty resting on every one of us who depend for our living on the operating engineer's vocation, to study with open mind and carefully the question in its relation to ourselves and to the owners of plants as well. We must come to a conclusion as to what is wanted in order for us to solve it, and also how to attack the solution of it.

If the operating engineers of today, and those who hope to become such, could be made to realize: first, their common interest; and second, the community of interest existing between them and the respective plant owners, we would be far on the way to a solution.

The fact stands out with increasing clearness, that the vital problem before plant owners and operating engineers alike, is the need of securing the right candidates for engineer's license and positions of trust in the engine-room. In fact, the operating engineers must learn to see that their problem is a contest for personal fitness and efficiency, and that economy in production and consumption of power is the employer's problem and just demand.

Our generally prevailing methods of meeting this just demand are wrong and hurtful to both employer and employee.

It is a ruinous policy for all of us to allow a man to seek to receive a position for which he does not possess the needed qualifications and a trained practical experience. These facts realized, we ought to get together and drop distinctions, and willingly do our full duty to each other in diagnosing our case frankly. When we have agreed that the fault, to a great extent, rests with us as a class of artisans, we ought to begin at once to discuss the remedy, and when one is agreed upon, we must learn to apply it unsparingly.

What sense is there in complaining and finding fault with the plant owners, and in many cases treating them as natural enemies because they are not treating us right, when we really deserve much of it for what we do not do.

Likewise, it may, of course, with equal right be asked of the plant owners, if they do not think it rather unreasonable to expect the highest class of labor and the best results when they insist on twelve-hour watches every day and every night in the week.

THE TWELVE-HOUR WATCH.

Disregarding entirely his qualifications as a competent man, no one can deny the fact, that when a man is working twelve hours under ordinary engine-room conditions, he is simply not physically able to do full justice either to his job or to himself.

Long hours in the operating engineer's occupation cannot lead to anything but serious injury and danger to a man's health; continuing long hours of work in a hot engine-room he will eventually get sick and disgusted with everything and, being ill, his machinery is generally out of condition also. His family is disgruntled because real home life or a little sociability is not possible; and as for going to church, he cannot think of that. He has no time.

And thus, a man's system gradually

breaks down, subjecting him to all sorts of illness. Eventually he feels the real need of stimulants, and it is a serious truth that long working hours, unknowingly, lay the foundation for the power-plant worker's greatest enemy—the drink habit. Steam engineering and whisky make an explosive mixture.

No doubt, many plant owners will not like this statement, but it is, nevertheless, an evident and painful fact that this condition of affairs is brought on by the prevailing twelve-hour watches insisted on by many plant owners, much to their own detriment from a business standpoint.

It is an imperative necessity that all plant owners consider this condition, for it will be brought to their attention more and more forcibly that it must be remedied; and, remedying this, will do away with one of the most serious troubles existing in engine-rooms; namely, the lack of time to study, and physical inability to do good work; furthermore, it will tend to remove a most serious and real danger to thousands of men and their families.

The point for us operating engineers to see is the need of clearing ourselves from vulnerable spots, and making it impossible for the employer to find serious faults with our principles and methods. Only when we do this will it be possible for us to get a reasonable hearing and a chance to promote our cause.

Every power user who employs a central station, or an operating company in preference to his own crew, expresses plainly his dissatisfaction with the operating engineer, and he does this because he finds it necessary to reduce the expenses in his engineering department. The plant owner is making the change generally because he suspects ignorance and unfitness, with the resulting waste on the part of his crew.

It can, without fear of contradiction, be said that these charges lodged against the operating engineers are the two real causes of the plant owner's more or less prevalent dissatisfaction.

WHAT A COMMON-SENSE ACCOUNTING SYSTEM WILL DO.

That grafting is present in an occasional engine-room is largely due to the peculiar fact that many plant owners neglect a plain duty to their own business in not being willing to equip the plants with means which will enable not only the engineer, but the owner to follow the plant performance and the output every day; such means prevent, to a great extent, the possibility of having dishonest men making costly repairs and changes where there is no actual need for them.

The average employer does not apply the same methods of close accounting in the engine-room which he, under all circumstances, would apply in any other department of his business, and for this he is blameworthy. This is the first remedy he applies to any other part of his business, and why not keep books on the engine-room?

A common-sense accounting system is of great value to the engineer, in that it saves him from being charged with expenses not chargeable to his account, and at the same time he will find a daily cost-sheet to be an excellent teacher of himself and his men. These are points of more importance than is realized by many plant owners and engineers. In fact, no plant owner or ambitious engineer in large or small plants can long afford to neglect the need of making systematic operating accounting a regular adjunct of every engine-room where efficiency in the men and economy in the plant is wanted.

The fact that owners neglect these important points, presents a temptation and chance to do various wrongs, and the opportunity presented is eagerly grasped by many unscrupulous supply dealers and contractors handling, in most cases, inferior material and who, for that reason, are unable to succeed except by unfair means of competition.

The natural result of this lack of performance records and of operating accounts in the engine-room is that the head of the department can often continue unchecked with methods that put the expenses of the department entirely out of proportion to the benefits received by the owner.

The wish to sell unfair goods and to take advantage of unfair competition, a ready-tongued salesman, devoid of principle, and a weak engineer make a combination that produces the accomplished briber. It will certainly not be denied that he is the most prolific and chief source of corruption in engine-rooms.

The evil reputation of a few engineers ought not to be heralded everywhere by the operating companies and by central stations as true types of the operating engineer. Honest and hard workingmen suffer by it without any method of redress at present. That there is a real danger to our craft is attested by the fact that within recent years there have been organized what might be termed policing operating companies, who are to supervise us. The pernicious activity of the engineering supervising companies has been based on a condition more or less imaginary than real. That "graft was becoming a usual accompaniment to engine-room operation, and that in the purchase of oils, fuels and in the making of repairs it became the custom in more than one-half of the plants for the engineer to receive anywhere from 10 per cent. to 50 per cent. of the cost of the work," is not believable by any of us who know conditions at first-hand. Dishonesty is not more common in the engine-room than in any other calling.

The appeal to the fear of plant owners by telling them how hopeless it is for private plants to exist without kindergarten supervision are fast wrecking what was once the most promising of careers open to young men of a mechanical turn of mind who seek congenial and remunerative work.

It ought to be equally plain to engineers and men that both supervising companies and central stations calculate their volume of business is in exact proportion to their success in spreading the general belief that ignorance and grafting are rampant in the majority of engine-rooms. From this it follows that we cannot expect any real assistance from that source, however much some of them profess to labor for our cause.

The cry of graft is one of the fruitful causes of the employer's dissatisfaction. Such a charge is given more importance than it really deserves, because it is sure to command every employer's instant attention.

IGNORANCE IN THE ENGINE-ROOM.

Reverting to ignorance in the craft as the other main cause of dissatisfaction, it must first be admitted that the engineer sometimes grows up ignorant and unmindful of the importance of economical operating performance, not because he has chosen to be so, but because he has worked so long that he has no time for reading and reflection. He has been tied so tight to his daily task that there has been no opportunity of learning. It is not just to blame the engineer and his men, since much of the responsibility ought to be put on conditions over which the individual is powerless.

That engineers know ignorance is common enough in the engine-room is attested by the work and lectures given in various engineer's associations. It is pleasing to note that this is also the fact in the Eccentric Firemen's Union. Indeed, we may say that in every association of engine-room workers which is fortunate enough to have clear-headed and broad-minded men in the management it is insisted that ignorance must be rooted out of the engine-room.

Many organizations of operating engineers and other engine-room work-

ers have been organized with the express purpose of overcoming this lack of proper knowledge among engineers; but they are seemingly not remedying the trouble. Some of these organizations barely exist, and show life to only a few favorite ones; others have broken down completely from being over-burdened by too much secrecy and clannishness, bad leadership and indefinite aims or no purposes whatever; others spend more time on pleasures than on serious study and the struggle for advancement.

Most men when they have received a license to care for engine and boilers, or have received a union card to work as engineers or able mechanics, too often consider it unnecessary to learn more. Likewise, many do not consider it a duty to help others to qualify for positions of a like nature, but are willing to let the young man get along as best he may.

VOCATIONAL PRIDE.

Some of us have begun to see the error of such conduct, but lack the needed spirit of activity and love of right to do our full part in lifting the level of our vocation.

Some attempts have been made in the right direction, but the result has not been encouraging; partly because the urgent need of the operating engineer's vocation has not been fully realized by the individual members, but mainly because the operating engineer and other plant workers have not been combined in one association with the fundamental aim of furthering education and a spirit of co-operation between themselves and plant owners. On the contrary, we are scattered in small bodies, many of which are completely at variance as to what are the real needs of the operating engineer and the plant owner.

That plant owners have certain duties which they must consider if we are to have a fair opportunity to do our part in the solving of this important and far-reaching industrial problem, I do not think will be denied by any of them who have seriously considered the question.

It is not my intention to offer theoretical views and schemes to meet the situation confronting the plant owner and the operating engineer. I wish only to call attention to facts based on experience; facts which must be considered by all concerned. In doing this I am simply trying to do my part to solve the problem by stating my view of the situation as I have found it in my own work in engine-rooms. I know from painful experience of many years the exertions of bodily strength and will-power, the drudgery, the hardships and the disappointments a man must go through if he wishes to make himself a thoroughly able operating engineer while he is compelled to work unreasonably long hours under the trying conditions of the engine-room.

While in principle the employer's demand for higher efficiency and economy is perfectly correct and just, its realization in general practice is neither possible nor reasonable unless the men are enabled to devote some time to study and recreation. This they are not able to do where twelve-hour watches are in use.

I can assert without hesitation that it will not matter to the plant owner whether an operating company or his own men run the plant; real improvement cannot be expected so long as he insists on the twelve-hour watch. I firmly believe that the average employer, with his discerning business sense and humane point of view, needs to have the case fully explained and presented as only the man in the engine-room feels it and sees it, for him to clearly perceive the injustice in demanding improvement in his men when they are worn out by a twelve-hour day or night watch in a hot and often unsanitary engine-room.

CO-OPERATION.

We need co-operation among the men in the engine-room, and in turn the men need the plant-owner's good-will and assistance. Co-operation is the essential basis for success on which the plant-owner and his engineering crew must work. Let us all realize that co-operation and its tremendous power is the basis of all undertakings; without it success is impossible. It is used in offense and defense; its power is being recognized more and more, as is shown in the great business and labor consolidations of the present day.

These consolidations are all based on this old principle of co-operation, and their whole future success or failure depends entirely on how well its basic principle is understood and lived up to. Those who refuse to see or to admit that reward must be given for ambitious individual effort and personal merit and efficiency, and that the presence of these attributes determine the success of any undertaking, do not realize the full value of co-operation. Take away the reward for individual effort, and the vital enduring part of any co-operative scheme has been removed. No combination of any kind, be it capitalist or workmen, can exist or endure long unless provision is made for giving material reward for individual effort and efficiency. The demand for this is imperative and must be heeded in all cases according to the temper and circumstances of the men co-operatively acting together.

To argue that special reward for merit is not needed, and to listen to such arguments, will only complicate the contest going on; it will never right it. The demand for it may be held down for a while, but it will come forward again and again, since the belief in the right to such reward for individual merit is firmly rooted in human nature, and is the basic motive of all achievement.

The only reward for personal effort that is really appreciated by the working-man is a material one, consisting in a money value, the size of which must be according to, and depend entirely on the worker's ability and degree of individual effort. In other words, where a man shows ability and does better than a good average, he ought to be rewarded by a cash reward above his wages. The employer who adopts this method will be well rewarded in better work, higher economy, increased safety to machinery, and satisfied men. In fact,all signs indicate that this method of payment for work is the only sure and right course for employers to adopt if the reputation of this country is to be sustained by the continued belief that here, at least, every individual has a right to elevate himself, and is entitled to a fair measure of success according to his own merit.

THE PLANT OWNER'S POINT OF VIEW.

The question is, what will the plant owners do about it? Their answer is indicated by the increased business of the central station; and that they are not basing their decision altogether on the economy question between the isolated plant and the central station, but also on the personal equation of the operating engineer and his men. This is proved by the recent activity of operating and supervision companies, who, in many cases, step in and completely supplant the operating engineer, or try to ruin his position and future.

That this statement is based on fact is evidenced by a pamphlet on engineering supervision and operation of power plants, mentioned editorially in *Power and Engineer,* December 29, 1908. The pamphlet referred to contained a statement which every thinking man ought to consider unfair to the operating engineer and his vocation in general; but this is only one of the plain signs indicating the way many employers are answering the question, and it is well for the operating engineer to heed the lesson before it is too late.

The proof of widespread dissatisfaction of power-users with the operating engineer, in both large and small

plants, can be seen in the tremendous increase of power supplied by central stations, taking the chances of employment away from hundreds of men already holding license, and reducing to nothing the chances of younger men who aspire to the operating engineer's vocation.

This increase in central station activities is not shown in private plants only, but in the city's own plants where it is an exception to find anything but central station power in use. The reason for such conditions is freely admitted, and it is found in the plain statement that electric power is bought from a central station because it is believed that it pays the user to do so.

It is entirely beside the question for engineers, single handed, or in associations, to explain or prove that power can be produced cheaper by the isolated plant. It is a well-known fact that even a small isolated plant, if well managed, can produce power cheaper than the central station will sell it.

This fact is recognized and proven by hundreds of operating engineers, to the satisfaction of the respective plant owners, and the central stations are aware of it. In spite of this known and admitted ability of a well-managed isolated plant to compete successfully, the central stations have a large increase in business every year. This proves conclusively that many owners find it to be either an outright paying proposition to buy power, or they have concluded, in the case of new buildings, that in addition to the advantage of reduction in the first cost of machinery, they are freeing themselves from the worry and expense incident to employing, often unwillingly, an unknown quantity for an engineer, who may cause all sorts of known and unknown expenses.

The power user may admit the possibility of saving money by having his own plant, and he would have it if he could be certain of the personal equation in his engineering crew. Unfortunately, he has no means of arriving at an intelligent conclusion, since the operating engineers have been so short-sighted as to overlook their real duty to themselves, as well as to the men who employ them, by not making it possible to supply tangible evidence of fitness, such as apprentice certificates, which could be used by the individual engineer, fireman or oiler when applying for a position, and which could confidently be accepted by the employer as fairly conclusive proof of the applicant's character and ability.

This very important duty being neglected by the operating engineers, the power user often concludes that the risk of having his own plant with its possible saving is too great, as compared with the central-station proposition, and in this view he is strongly urged by the central-station man.

In the case of new buildings the decision as to which is preferable—the central station or the isolated plant, is obviously based on argument only, and both the central-station man and the operating engineer may claim to be right, and they usually do. Nevertheless, the central station keeps the business and gets more because the power user does not base his business acts on talk and sentiment, but on what promises to be the surest and best means for getting results and peace of mind. In the case of old buildings, the operating company must be reckoned with, and here it is a fair contest based on the well-known rule of *the survival of the fittest.* All sides have an equal chance to make good, and the power user can be trusted to take that side which his knowledge and experience in business tells him will give the desired results. The outcome will ultimately depend on the ability of the men operating the isolated plant, including all from the helper and coal-passer to the chief, to prove their fitness to give the employer what he is entitled to, namely, results which will make it possible for any employer to see which method of procedure will give the greatest economy and peace of mind. In fact, it must be made possible for him to see and to appreciate the benefits which do exist in an isolated plant managed and operated as a business undertaking by his own crew in charge of a competent operating engineer and good man.

This can be done if the employer, the operating engineer, his assistants, and all the men make up their minds to run the plant with the sole purpose of developing every possibility in themselves and the machines. The vital truth, that if we wish success all must realize and build upon the common interests, the men and the employer.

WHAT WILL OPERATING ENGINEERS DO?

The next question is, what will the operating engineers and the men who hope to be engineers do about it? The isolated plants will continue to exist, and the employers must have somebody who can be trusted to do the thinking and planning to keep their plants in operation at an expense which can compete with the central station. Is it to be our men, or the operating company? That is the real and important question before the operating engineers to-day, because there is no doubt about the isolated plant being able to produce power for less money, and to do it more conveniently to the user, than the central station. In this connection, we can all agree with Mr. T. M. Kelsey, Lowell, Mass., when he says in *Power and Engineer,* Jan. 12, 1909, "that competent engineers with co-operation on the part of the employer makes a combination that cannot be beaten." Mr. Kelsey gives the best remedy possible for the solution of the whole problem: competency in men and the employers' co-operation.

To reach this desirable end, the chief operating engineer should insist on having sufficient means to properly run the plant. These include a common-sense system of accounting which will be a help and a guide to him in regulating the expenses and his work, as well as a medium of proper business intercourse with his employer. All guess-work as to operating costs must, as far as possible, be eliminated. The accounting system must be arranged with the one central idea that whatever the engineer and his men do, the expense involved, as well as the benefit derived, should be as an open book to the employer.

From the competitive point of view, it depends upon the operating engineer's ability as to whether the plant owner can afford to keep him in charge of the engine-room.

To make this possible, it is of importance to the employer that he shows willingness to make reasonable hours of work and material advancement possible. His willingness to make his mind up to do this rests, of course, primarily on the crew's success, in the all-deciding point of making it pay for the employer. If the operating engineer can do this, the average plant owner's business ability can be depended upon in all cases to make him willing to allow all reasonable demands of him and his men.

On the other hand, if we as a class do not prove to the plant owner's entire satisfaction that to keep us is the cheapest and best policy, nothing—neither more license legislation nor stronger unions—will ever compel him or make him willing or able to save us from the fate which will necessarily be ours, when the engineer, from a business standpoint, the only one possible, has been proven an inferior custodian to the central station or operating company.

Should it prove that the operating companies come out the victors, the existing license laws will relegate the operating engineer to a position where he is powerless to shape his own destiny or future, although he will still, before the law, be held responsible for the consequences of the acts of other people: In other words, he will be a legal figure-head, etc. He will be

stripped of all authority and position. Whatever an ambitious operating engineer may do for plant betterment will be to the operating company's credit, and not to his, because he will be only a cog driven and directed by the operating company's central engineering office. He will be given the longest working hours possible for seven days in the week, with far less pay per hour than a hod-carrier receives. All avenues to material advancement and promotion will be cut off or depend entirely on the good-will of the operating company.

Admitting that much is attempted and done for men who hold license as engineers, it still remains a singular fact that no notice whatever is paid by the operating engineers to the young men who some day hope to become members of their ranks, and how these men will qualify for the increasing importance of work and responsibility thrown on the man who is to take the chief operating positions now at hand and still coming, and how they, without trained experience, are to satisfy the employer who is to have the benefit of the newly made engineer's first attempt and quest for experience is hard to imagine.

A PROPOSED CAMPAIGN.

It is also significant that no concerted attempt has been made by the operating engineers to get the plant owner's opinion, much less his co-operation, on the situation, although he is the center around which the three-cornered contest between the central station, the operating companies and ourselves is raging often to his complete confusion. He is the prize we all want to claim as our own. Is it not reasonable that he is rather weary of it, and longs to be given a chance to put in a word? The central station and the operating company's men visit him, talk with him, and present all sorts of alluring visions of splendid savings that will be his if he will only put himself in their care and sign a contract to the effect that they, and they only, are capable of running that part of his business.

Would it not be a good policy for us to quit depending so much on our legislative entrenchments and do some drumming on our own account, as the others do, by frankly and modestly asking our employers to help and to co-operate in helping them run their own business with profit? We need not ask for contracts of any kind, but only ask their earnest and willing co-operation.

It is for the employers, operating engineers and their men to give the future careful and close attention, and the operating engineers must realize that the days of the untrained, personally irresponsible incompetent man in the engine-room are ended. We must see to it that he is either trained or pushed aside as a back number and out of place. His complete retirement from places of trust must be considered a need and a matter of course.

We must not alone realize this to be a duty, but we must act unitedly and systematically with this truth as a background for our methods of action and base our campaign for more reliable and better-fitted men, better conditions, as well as better chances for the plant owner to meet his obligations through co-operation with his employees.

Good understanding between the employer and employee, and mutual willingness to help each other in everything, can only be reached through earnest efforts, based on right and honest principles.

Such a campaign instituted by all engine-room workers, as well as plant owners, since they are just as vitally interested as we are, is bound to make itself felt by all concerned, because it will tend to reach the desired goal of cheaper power, providing we are sufficiently broad-minded, fearless and alert.

Such a campaign must be based on the proposition that the operating engineers, to gain the complete confidence of the power users and the public in general, must remove the causes of the existing dissatisfaction with them. To be in a fair way to succeed in doing this, we ought all, employers and men, be together in one society, since the problem before us is national in extent. Such a combination could fittingly be called the National Society of Operating Engineers.

A NATIONAL SOCIETY.

The fundamental aim of such a society would be to take a united and fearless stand based on a strong resolve to face the future, and together do our full share in the solution of the economic problems confronting us.

The use of the time-honored power which resides in co-operation, based on correct principle, and executed by correct methods, will ultimately bring us nearer to the point where there will be peace and harmony between employer and employee.

It will teach both sides the need of fair treatment, a treatment which, in all cases, ought to be based on the most honored, practical rule of human conduct: "Do unto others as you wish to be done by." If we really and honestly try to let that rule be our guiding principle, we are certain to win out. We must show the employers what we need, and prove to them that our need is also their need. We must have a recognized means through which we can express our needs, and convince them of the community of interest between us. We must learn to study and to set forth our own case, and not to depend on others who do not always wholly understand our conditions and needs. By such concerted action we can, with more ease and hope of success, show the way by which improvement for both sides can be secured. Set rules and regulations cannot be made to work in every case. To give flexibility to the proceedings of the society a central forum should be provided as a help in arranging conditions to put both owner and men in a fair way to final satisfactory adjustment of differences.

This forum must be competent to sit as a sort of arbitration court before any plant is given over to a central station or to an operating company by which step both the owner and the men generally lose.

The only sure way to win the regard and confidence of owners and men is by the method outlined, for employers and employees can never expect to work together in harmony unless there is mutual respect and co-operation in educating and helping each other to regard the Golden Rule as the only workable and enduring principle on which we can safely base all our actions.

In concluding, the problem before us may partially be summed up under the following heads:

A national society of operating engineers, including plant owners, as advisers and associate members, ought to be organized to facilitate the work which must be done to solve the problem; this society to be a central vocational forum, where the employer and employe of all grades may, at all times, meet to discuss conditions and agree on principles and methods of action best suited to the needs of all.

In order to secure better-fitted condidates for positions as operating engineers, the society ought to institute a suitable apprenticeship method for plant workers. That this aim may be furthered, ambitious young men ought to be included in the proposed society as probationary machinery operators and firemen apprentices; and to encourage such young men in their work for self-improvement. The society should issue a service certificate to any young man who has the prescribed education and who receives the employer's and the chief operating engineer's recommendation for two years' continuous service, as being of

good habits and possessing mechanical adaptability. This certificate would entitle the bearer to be entered in the membership book as an apprentice member and to seek experience in other engine-rooms.

To further the needed spirit of vocational pride, apprentice members with a clean record and four years' practical experience, thorough and honest training in useful engine-room work, either as machinery operators or firemen, will be given the society certificate of merit and recommendation as a proof of possessing practical skill and for having passed the prescribed course of study required of machinery operators and firemen. This would entitle the bearer to be entered in the membership book as a junior member.

Ambitious junior members of the society having a clean record and at least 5 years' actual engine-room experience, including a specified time as machinery operator and firemen, will, upon giving satisfactory proof of having passed the prescribed course in plant management, receive the society certificate and recommendation as an operating engineer, entitling the bearer to have his name entered in the membership book as a full member of the society.

It must be our aim to adopt practical methods, which will enable the operating engineers to organize a systematic and effective educational campaign in behalf of the vocation, that its standing may be elevated and its importance better appreciated by its present and prospective members, as well as by the plant owners and the public in general.

We must make it our aim to base the work of the proposed Society on such enduring principles and methods that eventually the prestige and value of the operating engineers vocation will be such that the very best young men will be drawn in as apprentice members.

To make it possible to reach our goal, we must all, employers and employees alike, learn that co-operation and willingness to help each other are the basic principles by which we must lay our course.

Tests of Electric Meters in New York City

A REPORT on the various types of electric meters in use in New York City, made by Cary T. Hutchinson for the Public Service Commission, contains some interesting facts regarding their accuracy under various conditions. It was found that all the direct-current meters submitted for test were capable of accurate registration while in first-class condition and properly mounted. They were all Thomson Recording Wattmeters, made by the General Electric Co.

The report gives an outline specification embodying the various points necessary in a meter for accurate service. The range of load and voltage called for are considerably in excess of the variations which ordinarily arise under service conditions, these wide limits being chosen to get a measureable difference in registration, and at the same time to indicate the maximum error that might arise under extreme conditions of operation; the limits of error in registration specified refer to the tests made under laboratory conditions, where the meter can be carefully mounted and adjusted and every precaution taken to secure high accuracy in the measurement of the various quantities involved.

In regard to the adjustment of the meter at full load and light load, particular attention is called to the fact that in a number of the meters there is a marked shifting from day to day of these two supposedly fixed points on the registration curve (in some cases as much as two per cent.), the meter being left untouched in the laboratory, subject to no outside influence except slight variations in the room temperature.

To determine just what causes these variations would require a prolonged investigation; they are, however, probably due to temperature effects. In making comparative tests under various conditions, therefore, frequent determinations of the accuracy of registration at these two points should be made and the proper correction allowed for any change that may occur, particularly if the tests extend over a considerable period.

1. *Mechanical Construction.*

Material and workmanship to be first-class in every particular, all fixed parts to be securely held in their proper position, moving element to be as light as possible consistent with proper strength, and all bearing surfaces to be designed to reduce friction to the minimum.

2. *Accuracy of Adjustment.*

Meter to be capable of adjustment to register with an error of less than one per cent. (1%) the true value of energy supplied through the meter at rated voltage and at either rated current or 10 per cent. of rated current.

3. *Accuracy of Registration Under Various Conditions of Load and Voltage.*

After the meter has been adjusted as specified under Clause 2, it shall register with an error of less than two per cent. (2%) the true value of the energy supplied through it at rated voltage at any current from 10 per cent. of rated current to 150 per cent. of rated current; the error in registration at 5 per cent. of rated current and at rated voltage shall not be greater than seven and one-half per cent. (7.5%); the change in the accuracy of registration for a 10 per cent. change in voltage either above or below normal shall not exceed three per cent. (3%) at rated current of five per cent. (5%) at 10 per cent. of rated current.

4. *Accuracy of Three-Wire Meters.*

The change in the accuracy of registration of a three-wire meter when either one of the current coils is cut out of circuit shall not exceed three per cent. (3%) for rated current through the remaining coil.

5. *Effect of Change in Temperature.*

The change in registration of the meter when the temperature of the room in which it is installed rises from 50° to 100° F. shall not be more than five per cent. (5%) at rated voltage at either rated current or 10 per cent. of rated current.

6. *Effect of Temporary Overloads.*

A temporary overload (three seconds) of 300 per cent. of rated current applied five consecutive times shall not cause a permanent change of registration at rated voltage and rated current of more than two and one-half per cent. (2.5%) for meters having a rated current capacity of less than 600 amperes, or of more than five per cent. (5%) for meters of larger capacity; the permanent change in registration at 10 per cent. of rated current and rated voltage, due to such overloading, shall in no case exceed 5 per cent.

7. *Loss in Current Coils.*

For meters rated at 50 amperes or less the total loss in the current coils at rated load shall not be more than one per cent. (1%) of the total power supplied; for larger meters this loss shall not exceed two-tenths of one per cent. (0.2%).

This specification covers only those characteristics of the meter which may effect the accuracy of registration from the consumer's point of view; that is, a meter which fulfils the above specification, will, when properly installed and correctly adjusted, show no tendency to over-register, within the limits specified, under normal conditions of operation. There are, how-

ever, a number of other points which affect the excellence of an energy meter; namely, the friction of the moving element, the power lost in friction, in the potential circuit, and in the disc, the speed of the meter, the driving torque, the weight of the moving element, the ratio of driving torque to weight, and the ratio of driving torque to frictional torque. These data have been determined for all meters submitted, and in general it may be stated that it is desirable that a meter have the least possible friction, small loss in potential coil, high ratio of driving torque to weight, and high ratio of driving torque to frictional torque.

The following points regarding the design and use of the Thomson wattmeter should also be noted:

1. The internal connections of a Thomson meter are such that the losses in the meter are borne in part by the supply company and in part by the consumer; the former stands the losses in the potential circuit, disc, and frictional resistance, the latter pays for the loss in the current coils. Consequently, from the consumer's point of view, the loss in the current coils only is of importance.

2. A heavy overload, such as a short circuit in the installation supplied through the meter, may cause a considerable weakening of the permanent magnets, and thus cause the meter to run fast. No attempt, however, was made to determine the effect of overloads greater than 300 per cent. of full load, as it is always possible to protect a meter from heavier overloads by installing proper fuses or circuit breakers. If the meter is not so protected the consumer should be warned that a heavy short circuit may make his meter run considerably fast, and a readjustment of its speed after such a heavy overload should be requested. It should be noted, however, that the later designs of the Thomson meter are much less affected by overloads than the earlier types, as the magnets are so designed and are so arranged with reference to the current coils as to reduce this effect to a minimum.

3. The magnetic field produced by other instruments or wiring in the vicinity of a wattmeter may affect the registration to a considerable extent; particularly when the meter is installed on a switchboard on which are located bus-bars carrying heavy currents; the result may be either an over-registration or an under-registration, depending on the direction of the stray fields. By adjusting the meter after it is installed the effect of any constant stray field can be compensated for, but accurate registration is impossible when these effects are large and variable.

4. A wattmeter should always be installed in such a manner as to reduce mechanical vibrations to a minimum, as the friction of the meter is largely affected by such variations, which may cause the meter to run continuously or to "creep" when no current is being supplied through it.

As with the direct-current meters, specification was formulated for alternating-current meters, based on tests and examinations, stating the limits of the permissible error in registration for such meters when in first-class condition.

The following "types" of meters were found to comply with this outline specification:

GENERAL ELECTRIC COMPANY

Type I
" IP-2
" D-3

WESTINGHOUSE ELECTRIC AND MANUFACTURING COMPANY

Round Type—two wire
Type A—three wire, self contained
" A—three wire, with current transformer
" B—two wire
" B—two wire, prepayment
" C—two wire
" C—three wire

STANLEY INSTRUMENT COMPANY

Type G—2d form
Jewel type

FORT WAYNE ELECTRIC WORKS

Type K.

These types are described in detail below. Although only one meter of each type was tested, Mr. Hutchinson was of the opinion that a meter properly constructed in accordance with the design of any one of these types will, when in good condition, register accurately within the limits specified. In the case of those meters designed to be used with a current transformer the tests have covered both the meter and the transformer, and in the specification the meter and the transformer are to be considered as a unit.

The following meters failed to meet the requirements of the specification in certain particulars; with the exception of the Westinghouse type C, polyphase, these are all meters of early design and are no longer manufactured. A more extended investigation of these types may show that the discrepancies noted are due to defects in the individual meters rather than to defects in design. The only meters departing radically from the specification are the Duncan meters, made by the Siemens-Halske Company of America, and the General Electric Company's type C-1, the large errors shown by these two meters being due to excessive friction in the bearing surfaces, which could not be eliminated.

GENERAL ELECTRIC COMPANY

Type C-1—On account of the abnormal friction in this meter, the error at 10 per cent. rated current was 36.0 per cent. with the registering mechanism in place; a second meter of this type was also tested, but gave no better results. On account of this large error at light load the tests under various conditions of voltage, power-factor, etc., are of little value as indicating the effect of varying these factors on a meter of this type capable of proper adjustment.

Type C-4—This meter comes within the specification except at 10 per cent. rated watts and 50 per cent. power-factor, where the error was —4.6 per cent. as against ±4.0 per cent. allowed in the specification.

Type DF-2-PP—This meter comes within the specification, except at 100 per cent. rated watts, 110 per cent. frequency and 75 per cent. power-factor, where the error was —4.4 per cent. as against ±4.0 per cent. allowed in the specification. The three-phase test was not made on this meter.

Type DF-2—This meter comes within the specification, except at 100 per cent. rated watts and 50 per cent. power-factor, where the error was —5.2 per cent. as against —4.0 per cent. allowed in the specification.

WESTINGHOUSE ELECTRIC AND MANUFACTURING COMPANY

Round Type, Three-Wire, with Transformer—This meter comes within the specification, except at two points, namely, at 5 per cent. rated current, where the error was 3.5 per cent. as against ±2.5 per cent. allowed in the specification; and at 10 per cent. rated watts and 50 per cent. power-factor, when the error was +4.9 per cent. as against ±4.0 per cent. allowed in the specification.

Round Type, Polyphase—This type of meter is not provided with any means of adjusting one motor element with respect to the other; it was therefore impossible to make the two elements exert the same effect on the disc. In this particular meter it was found that for 10 per cent. rated current through the two elements separately the errors were respectively —3.6 per cent. and +2.8 per cent., and with rated current through the two elements separately the errors were respectively —3.0 per cent and +3.4 per cent. When the current coils of the two elements were connected in

series the error in registration came within the specified limits. On account of the considerable difference in the accuracy of registration of the two elements separately, this meter would also fail to meet the requirements of the polyphase test.

Type C, Polyphase—The polyphase test on this meter showed a maximum difference of 3.1 per cent. in the accuracy of registration when operating three-phase and when operating single phase; to determine whether this comparatively large discrepancy is due to faulty construction of this particular meter or whether it is inherent in the design, would require a careful investigation of several meters of this type. In other respects this meter came well within the specification.

STANLEY INSTRUMENT COMPANY

Type G, Old Form—This meter comes within the specification, except at 10 per cent. rated current and 110 per cent. frequency, where the error was +2.3 per cent. as against ±2.0 per cent. allowed in the specification.

SANGAMO ELECTRIC COMPANY

Type Gutmann—This meter failed to come within the specification at 10 per cent. rated current and 90 per cent. voltage, where the error was —4.8 per cent. as against ±2.0 per cent. allowed in the specification; at 10 per cent. rated watts and 50 per cent. power-factor, where the error was —9.0 per cent. as against ±4.0 per cent; also a change in temperature of 50° F. caused a change in the registration of 7.0 per cent. at 10 per cent. rated current and 5.5 per cent. at rated current, as against 4.0 per cent. allowed in the specification. This meter was found very unstable in inaccuracy, changing considerably from day to day.

SIEMENS-HALSKE ELECTRIC COMPANY OF AMERICA

Type Duncan—The error in the registration of this meter at 10 per cent. rated current was —12.7 per cent. as against ±1.0 per cent. allowed in the specification. On account of this large error at light load the tests under various conditions of voltage, power-factor, etc., are not a fair indication of the effect of varying these factors in a meter of this type capable of proper adjustment.

As some of the older Thomson commutator wattmeters are still in use in this district on alternating-current circuits, one of these meters, General Electric Company's Type D-2, Maker's No. 684034, was tested on a 60-cycle, alternating-current circuit at 100 per cent., 75 per cent. and 50 per cent. power-factor. The errors in registration under the various conditions were as follows:

Watts in per cent. of rated watts.	100% Power-factor.	75% Power-factor.	50% Power-factor.
5	—2.0	+5.5	+11.0
10	—0.6	+4.5	+10.0
100	+0.5	+2.4	+ 4.5

that is, the meter runs fast on low power-factors. These results would be expected since, on account of the reactance of the potential circuit, the current supplied through the meter at low power-factors lags behind the current in the potential circuit by a smaller angle than it does behind the impressed voltage. Commutator wattmeters therefore are suitable only for measuring energy supplied at a power-factor of practically 100 per cent.

SPECIFICATION

1. *General.*

In the case of a three-wire single-phase meter, the limits of error specified, unless otherwise stated, refer to tests made with the two current coils connected in series and rated voltage applied to the potential circuit. In the case of a polyphase meter the limits of error specified, unless otherwise stated, refer to tests made with single-phase current, with both current coils of the meter in series and the two potential circuits in parallel and connected to a single-phase source of pressure.

2. *Mechanical Construction.*

Material and workmanship to be first-class in every particular, all fixed parts to be securely held in their proper position, moving element to be as light as possible consistent with proper strength, and all bearing surfaces to be designed to reduce friction to the minimum.

3. *Accuracy of Adjustment.*

Single-phase meters to be capable of adjustment to register with an error of less than one per cent. (1%) the true value of energy supplied through the meter at rated voltage and frequency and 100 per cent. power-factor, at either rated current or 10 per cent. of rated current.

Each element of a three-phase meter to be capable of independent adjustment so that the meter will register on a single-phase circuit with an error of less than one per cent. (1%) the true value of the energy supplied at normal frequency and 100 per cent. power-factor through either element alone, for either rated current or 10 per cent. of rated current through that element, with normal single-phase voltage applied to both elements.

4. *Accuracy of Registration Under Various Conditions of Load and Voltage.*

After the meter has been adjusted as specified under Clause 3, it shall register with an error of less than two per cent. (2%) the true value of the energy supplied through it at rated voltage, frequency and 100 per cent. power-factor at any current from 10 per cent. of rated current to 100 per cent. of rated current; the error in registration under the same conditions at 5 per cent. rated current and 150 per cent. rated current shall not be greater than two and one-half per cent. (2.5%); the change in the accuracy of registration at rated frequency and 100 per cent. power-factor for a 10 per cent. change in voltage either above or below normal, shall not exceed one per cent. (1%) at either rated current or at 10 per cent. of rated current.

5. *Effect of Change in Frequency and Power-Factor.*

A change in the power-factor of the load supplied through the meter at normal voltage and frequency from 100 per cent. to 50 per cent. lagging shall not cause an increase in the speed of the meter at rated watts of more than two per cent. (2%), or a decrease of more than 4 per cent. (4%) and shall not cause an increase or decrease of speed at 10 per cent. of rated watts of more than four per cent. (4%).

A change of 10 per cent. in the frequency of the current supplied through the meter at normal voltage and 100 per cent. power-factor shall not cause a change in the accuracy of registration at either rated current or 10 per cent. of rated current of more than two per cent. (2%).

A change of 10 per cent. in the frequency of the current together with a change in the power-factor from 100 per cent. to 75 per cent. lagging, the voltage being held at its rated value, shall not change the speed of the meter at either rated watts or 10 per cent. of rated watts more than four per cent. (4%).

6. *Accuracy of Three-Wire Single-Phase Meters.*

The change in the accuracy of a three-wire single-phase meter at rated voltage, frequency and 100 per cent. power-factor, when either one of the current coils is cut out of circuit shall not exceed two per cent. (2%) for rated current through the remaining coil.

7. *Accuracy of Polyphase Meters.*

A polyphase meter when adjusted on single-phase current, as described above under Clause 3, shall also register on a polyphase circuit at rated voltage and frequency within one per cent. (1%) of the same accuracy shown on the single-phase test, both at 10 per cent. rated current and at rated

current at both 100 per cent. power-factor and 50 per cent. power-factor.

8. *Effect of Change in Temperature.*

The change in registration of the meter when the temperature of the room in which it is installed rises from 50° to 100° F. shall not be more than four per cent. (4%) at rated voltage at either rated current or 10 per cent. of rated current.

9. *Effect of Temporary Overloads.*

A temporary overload (three seconds) of 300 per cent. of rated current applied five consecutive times shall not cause a permanent change of registration at rated voltage at either rated current or 10 per cent. of rated current of more than one per cent. (1%).

10. *Loss in Current Coils.*

The total loss in the current coils of the meter at rated current shall not exceed five-tenths of one per cent. (0.5%) of the rated watts of the meter.

As in the case of the direct-current meters, this specification covers only those characteristics of the meter which may effect the accuracy of registration unfavorably to the consumer. The following points regarding the design and use of alternating-current wattmeters should also be noted:

1. The internal connections of these meters is such that the losses in the current coils of the meter are borne by the consumer; the other losses are borne by the Supply Company.

2. A heavy overload, such as a short circuit in the installation supplied through the meter, may cause weakening of the magnets and thus cause the meter to run fast, but the effect of such overloads on alternating-current meters is, as a rule, not as great as with direct-current meters.

3. Unidirectional stray magnetic fields of constant magnitude have no effect on the registration of an alternating-current meter; fluctuating stray fields or fields due to alternating-current circuits in the vicinity of the meter may, however, affect its registration. By adjusting the meter after it is installed, the effect of any such field of constant magnitude can be eliminated, but accurate registration is impossible when such stray fields are large and variable.

4. Care should be taken to install the meter in a manner to reduce mechanical vibrations to a minimum; the final adjustment of the speed at 10 per cent. and 100 per cent. rated current should be made after the meter is installed and connected, taking the voltage and current for this purpose from the supply mains.

5. On account of the high reactance of the potential circuit of an induction meter, together with the fact that the coils in this circuit are wound on iron cores, the effective value of the current flowing in this circuit for a given impressed voltage will depend upon the shape of the pressure wave; consequently, the torque and therefore the speed, for a given load supplied through the meter, will be a function of this wave shape. In case the pressure on a given circuit has a varying wave form, as may happen, for example, if the circuit is supplied from different generators at various times, the effect of the maximum variation in wave form on the accuracy of the meter should be determined, and no meter should be allowed on this circuit which is appreciably affected by such variations. If the pressure on the circuit has a constant wave form, even though it may not be a true sine wave, then, by adjusting the meter after it is installed, using for this purpose the pressure on the supply circuit, the particular form of this wave will be immaterial, provided the accuracy of the standard with which the service meter is compared is not affected by wave form variations. In the case of a polyphase meter, each element should be adjusted to read correctly when connected to the particular phase on which it is to operate.

A High-Tension Direct-Current Railway

The recent inauguration of service on the Pittsburg, Harmony, Butler & New Castle Railway, brings to mind the fact that it is the pioneer road in the field of high-tension direct-current railway electrification. Although the Indianapolis & Louisville Railway was the first road in this country to use 1200 volts on the trolley, the plans and specifications for the Pittsburg, Harmony, Butler & New Castle Railway were prepared at an earlier date.

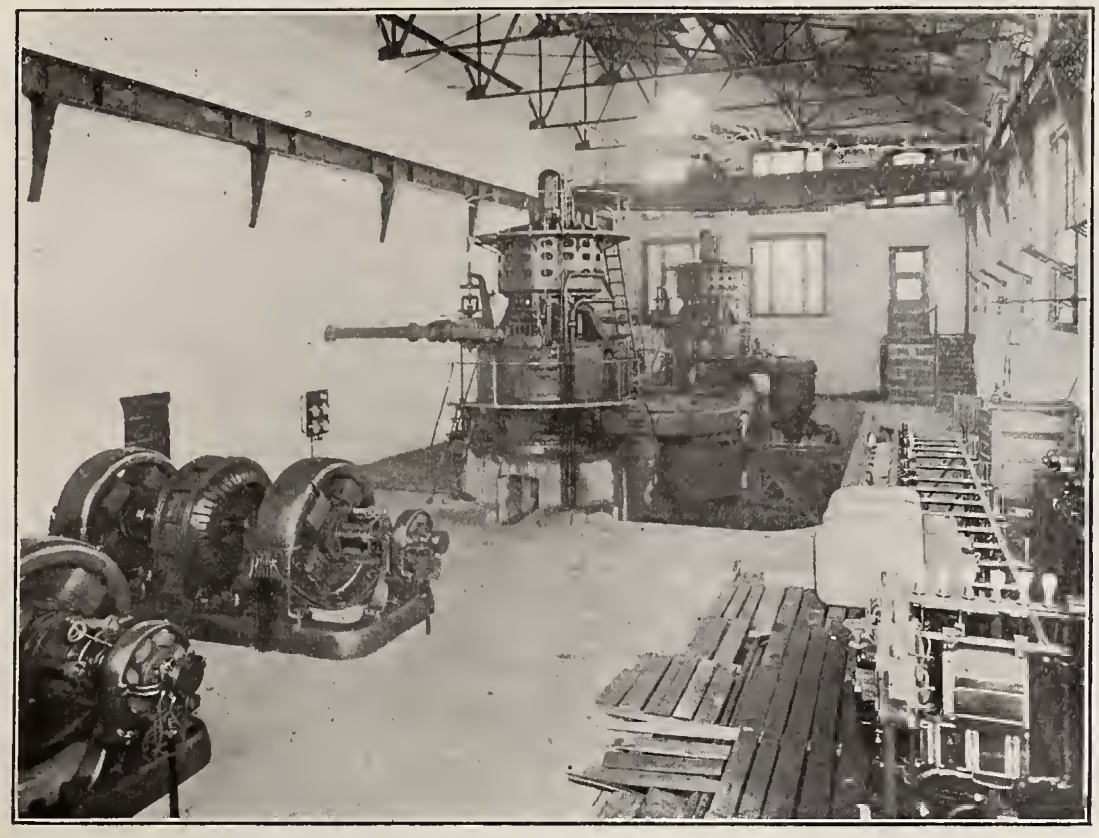
Power is generated at Harmony Junction by two 1300-kw. three-phase 60-cycle Curtis steam turbines of the vertical type, and transmitted at 13,200 volts to substations located at Shenango and Perrysville. The turbines are standard machines with two rows of buckets per stage, and are equipped with mechanically-operated valves and oil stop bearings. They operate condensing, the usual vacuum obtained being 28¼ in. In each of the substations there are two motor-generator sets, each set consisting of two 200-kw. 600-volt direct-current generators, direct connected to a 425-kw. 13,200-volt synchronous motor. The armatures of the two generators are connected in series, giving a trolley potential of 1200 volts. A

A BIT OF THE LINE OF THE PITTSBURG, HARMONY, BUTLER & NEW CASTLE RAILWAY.

substation in the power-house is similarly equipped and supplies both the Butler section and the central portion of the system.

With the exception of 4 miles of 600-volt trolley on the city lines at the Pittsburg end, the entire railway system is operated at 1200 volts. A grooved No. 4/0 trolley wire is used, this being strung double the entire length of the road. There are at present 14 four-motor passenger cars in use, although in the near future two cars for freight service will be put in operation.

The motors on both the passenger and freight cars are of the G. E.-205 commutating-pole 600/1200-volt type and are connected into two groups of two in series, this grouping being the same for both the 600 and 1200-volt service. With the exception of extra insulation on the motor circuit, the control is practically the standard automatic form of type M control. Control connections are made so that should the motorman release the controller handle power will be shut off the motors and the brakes applied. The brakes used are of the standard G. E. Emergency Straight Air Type, with a differential form of governor



INTERIOR OF THE STATION OF THE PITTSBURG, HARMONY, BUTLER & NEW CASTLE RAILWAY.

A SECTION OF THE ROAD ACROSS A RAVINE.

for multiple-unit operation. When the car is on the 1200-volt trolley, current for lights and the air compressor and control circuits is furnished at 600-volts by a dynamotor.

There are 65 miles of single track and at the Pittsburg end of the road double track is laid for 11½ miles, 80-lb. standard rails being used. The maximum grade is 8 per cent., although in the hilly country grades of 5 per cent. are numerous.

All the electrical apparatus used in the power-house and substations and on the cars was furnished by the General Electric Company.

Telephone Booth Fans

To anyone who has occasion to use long-distance telephone booths at all, the telephone booth fan manufactured by the Westinghouse Electric & Mfg. Co., of Pittsburg, Pa., and illustrated herewith, will be of special interest.

Though these fans have the appearance of a toy, they will be found of real service. The motor is supported by springs from an arm screwed to the side of the booth, and may be tilted or turned through a wide range. The springs prevent any transmission of vibration from the motor to the telephone, and as the fan is noiseless, the use of the telephone is in no way affected.

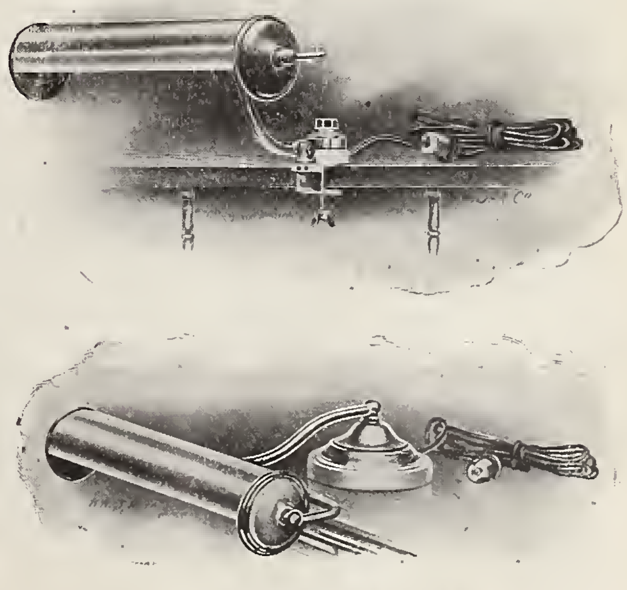
As booths are usually provided with several small holes, the air is circulated even with the door closed, but, of course, the best ventilation comes when the door is opened. The fan is kept running all the time and consumes about one-quarter of the cur-

TELEPHONE BOOTH FAN MANUFACTURED BY THE WESTINGHOUSE COMPANY.

rent required by an ordinary 16-c-p. carbon lamp. A regulating switch is provided in the base of the bracket from which the motor is suspended, by which the speed may be adjusted to three values, any one of which may be used for running indefinitely. The movement of the air is dependent upon the speed of the fan, as is the amount of power required. In some booths the lowest speed of the fan is sufficient. At the usual rates for power, 10 cents a kilowatt-hour, it would cost a cent and a half to run it all day long.

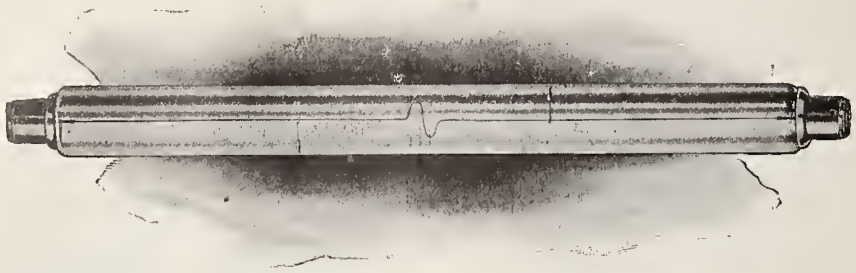
Linolite Desk Lamps

A variety of new styles in desk fixtures for use with the linolite tubular incandescent lamp have been re-



LINOLITE DESK LAMPS.

cently placed on the market by the H. W. Johns-Manville Co., 100 William Street, New York City. The accompanying illustrations give an ex-



THE TUBULAR LINOLITE BULB.

cellent idea of some of the varied styles. As is obvious, the great advantage of the linolite tubular incandescent lamp for desk use lies in the wider area of distribution of the light, owing to the great length of the filament tube. The fixtures are supplied in three finishes: burnished brass, oxidized copper and gun-metal.

New Catalogues

Anyone interested in fuel economy will find much of interest and value in Bulletin 368 of the United States Geological Survey, dealing with washing and cooking tests of coal, made at the fuel-testing plant at Denver, Col.

A folder sent out by the Western Electric Co. treats of an electric extension bell designed for calling in noisy places. It can be used either as a telephone extension bell or as an alternating-current signal bell on circuits of not more than 220 volts and 25 cycles.

Advance partial lists of the recording pressure and vacuum gauges are given in a bulletin sent out by the Bristol Company, of Waterbury, Conn. The various sizes of charts, with the many different kinds of graduations, are fully illustrated.

The Emerson Monthly, issued by the Emerson Electric Mfg. Co., of St. Louis, Mo., is devoted largely to fans. Some space is also given up to a portable suction cleaner, a motor-driven air compressor for dentists' and physicians' use, and also the usual motor stock list.

A pamphlet recently sent out by the C. W. Hunt Co., of West New Brighton, New York, deals with coal dealers' supplies, including mast and gaff fittings, automatic railways, chutes and screens, steel coal tubs, roller-bearing blocks and "Stevedore" manila rope.

A pamphlet deserving exceptional notice is that recently sent out by Joseph T. Ryerson & Son, of Chicago, "the iron and steel department store." Boiler furnaces, lugs, hangers, braces, rivets, flue cleaners, flue welders, friction saws, keyseating machinery, crank-pin turning machines, steam hammers, riveters, brakes, presses and special sand tools are some of the products handled by this company, together with steel and iron in the many forms needed by manufacturers. The typographical work of the book is excellent.

Electrical instruments are fully illustrated and described in a bulletin recently issued by the Wagner Electric & Manufacturing Co., of St. Louis, Mo. Standard direct-current and alternating-current types, together with special types, are described, and also potential and series transformers and instruments of the portable type.

The March bulletin of the National Electric Light Association contains notices of work of the various committees, and the continuation of an abstract of papers read at a meeting of the Philadelphia Electric Company, on "Load Factor, Diversity Factor and Power Factor." The question box, as usual, contains questions and answers on live topics.

A pamphlet just issued by the General Electric Company contains a comprehensive list of motor-starting and speed-controlling devices, both automatic and non-automatic starters. Each device is illustrated and briefly described, and the pamphlet will be of value to all interested in any way with motor drive. Another publication issued by the company is devoted to the Curtis steam-turbine generator. This bulletin gives many of the details of construction, with interior views and cross sections of various parts of turbine and generator. It describes large and small turbines of vertical and horizontal types, and contains illustrations of numerous representative Curtis turbine installations. Curves are given to show the relative economy of a 4-cylinder compound engine and a Curtis-turbine unit. As in so many other reports of turbine economy tests, however, the relative steam consumption of the condensing auxiliaries is not given. It would be interesting to know just how the two types would compare if this were included.

Personal

At the annual meeting of the Chicago Mica Company, held in Chicago, April 14, 1909, M. L. Kohler, of Philadelphia, was elected president.

H. B. Logan, president of Dossert & Co., of New York, is visiting the Western trade of the company. Mr. Logan, who will go to the Coast on this trip, says he expects to secure some big business before he returns.

Obituary

John Chamberlin Fish, well known to the electrical industry as president of the National Electric Lamp Association and of the Shelby Electric Company, of Shelby, Ohio, passed away suddenly on Friday, April 16, after an illness of only four days. He was born in Sheldon, Vt., on April 14, 1864. At an early age he moved to Ohio and secured his education in the public schools of Akron and Shelby, eventually graduating from Kenyon College at Gambier.

Mr. Fish first became identified with the electrical business when he organized, in 1896. The Shelby Electric Company, which owes its great success to his extraordinary ability and determination. At a later date Mr. Fish also became president of the National Electric Lamp Association, the formation of which was greatly due to his efforts.

At the time of his death, aside from being interested in the electrical business, Mr. Fish was president of the following companies: The Shelby Printing Company, The Shelby Water Company, The Ohio Seamless Tube Company and The Auto Call System Company, as well as vice-president of The Shelby Telephone Company, and a directer of the Citizen's Bank; all of these being located in Shelby.

Aside from endeavoring to benefit his place of residence in business ways, Mr. Fish also devoted a great deal of his time to the intellectual side, being president of the Board of Education. He was a member of the Knights of Pythias and Elk lodges, and was president of the Colonial Club of Shelby and the Shelby Business Men's Association.

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NOTICE TO ADVERTISERS

Insertion of new advertisements or changes of copy cannot be guaranteed for the following issue if received later than the 15th of each month.

CONTENTS

Core vs. Shell Transformers

Very lately there has been a great deal of controversy through some of the technical journals about the parenthood of the new type of small transformers recently placed on the market by the General Electric and Westinghouse companies, the General Electric referring to its new type of transformer as a core type and the Westinghouse Company referring to its new type as a shell type of transformer.

Both units are identical in their fundamental features. Both units are composed of several nearly circular and concentric coils in which the iron after passing through the opening of these coils divides into four equal sections 90 degrees apart. The Westinghouse Company has endeavored to show by sketches that the new form is an evolution from the shell type, and the General Electric Company has assiduously endeavored to establish by similar sketches that the new form is a natural development from the core type—but really, what do we care! It is only a matter of which way you walk around the imaginative circle of evolution. Either direction brings you to the same result.

The popular idea as to what constitutes a core or a shell-type transformer has been that with the shell type a large part of the coils was enclosed within the iron, and in the core type of construction a large part of the iron was enclosed within the coil. In either type, however, a large part of both the iron and coil was directly exposed to circulating oil. The definition of these two types, however, is indefinite, and they have been distinguished principally as the two makes of the manufacturers. In the new type, therefore, which is being manufactured by each company, it is rather difficult to state whether it is a shell or core type of construction. But this is not of any consequence, for it is only to the partly circular and thin type of coil that this new type owes its merit, and not to the form of magnetic circuit.

From a manufacturing standpoint, the new type is attractive, for the reason that it more nearly approaches the commercially ideal type than any type hitherto made.

As is well known, the principal argument advanced and claimed for the core type of transformer has been the ease with which circular coils lend themselves to insulation.

Sharp corners are largely avoided, especially in the outside coils, and this makes a less risk of breaking insulation at sharp corners in winding the coils. Besides, this form permits the use of mica insulation, which is certainly one of the best insulation materials that can be used. Another distinct advantage in circular coils is that the coil being very thin, the difference in expansion between inside and outside layers is very small compared to what it would be in a high, narrow coil, such as was used in what was originally known as the shell type of construction. As the success of a transformer depends very largely on its durability to stand strains in service, the advantages of a cylindrical coil are evident. The new type has many of the good points of the core type on account of its cylindrical coils, and has the additional advantage that it can be built cheaper than the superseded types.

Exhaust Steam Turbines

Within the last year the attention of the power-plant fraternity has been directed to the advantages of the low-pressure steam turbines as an adjunct of reciprocating engine plants. As was pointed out by Mr. J. R. Bibbins in a paper read before the Canadian Society of Civil Engineers a few months ago, the evolution of the idea came through the work of Hon. C. A. Parsons, to whom the world is indebted for so much of the expansion of the steam turbine in the last few years. Although some of the greatest advantages of turbine drive are found in connection with the use of the high-speed generator, in marine practice also the turbine has found a field of usefulness that has led to many striking results.

Experiments along a wide range of conditions have shown pretty conclusively that the reciprocating engine and the turbine each have their own points of superiority, both afloat and ashore. The analysis of these points has shown that with the increase in the pressure of the operating fluid the cylinder and piston combination has shown up well, although even then it has had its difficulties as to lubrication and similar points. At the other end of the working range—as everyone has noticed—the reciprocating scheme has had its hard going. The difference in the sizes of the working parts of the high- and low-pressure ends of a compound engine give an indication of the way the land lies.

As the line of atmospheric pressure is crossed the limitations of the low-pressure cylinder are yet more pronounced. The ratio of the variations in pressure due to cylinder condensation to the total range of working pressure becomes so large that the benefits of a high vacuum fall to the wrong side of what theory would lead us to expect. By the same considerations where the admission pressure of the turbine is at or near the atmosphere, the proportional benefit from an additional inch or two of vacuum is very great, amounting in certain cases to as much as 25 per cent. of the total steam used for the change from 26 to 28 in. While this does not mean that the operation of the reciprocating engine is not materially improved by a high vacuum, it is, nevertheless, true that the addi-

tion of an extra inch of vacuum to figures such as are ordinarily carried in a condensing power plant, in the case of the low-pressure turbine, brings several times the improvement in steam consumption that it does in the case of the low-pressure condensing engine.

So, speaking broadly, it may be said that the region of highest efficiency of the steam-engine lies in the higher range of steam pressure, while that of the steam turbine, at least of the type used mostly in this country, it lies in the lower. So much is this true that so far the efforts to devise a turbine that will work satisfactorily in the ranges of heat and pressure that exist in a gas-engine has been unsuccessful.

The result of the establishing of the region of maximum advantage has led to the decision to unite the two types, and now we understand that a pair of transatlantic liners are to be equipped with a combined engine and low-pressure turbine power plant. The German steel companies have likewise introduced this feature in several of their recent plants, and the first installation in this country has been made in the South Chicago plant of the Wisconsin Steel Company, where the exhaust of an engine whose indicated horse-power is about 1000 has been made to drive two 250-kw., 1500 r.p.m. direct-current turbines.

At first sight it appears almost incredible that so much power can be taken from exhaust steam. Looking at the matter from the arithmetical side, the steam tables show that the total heat of one pound of saturated steam under a pressure of 150 gauge or 164.7 absolute is 1193.6 B.t.u. and its temperature will be 365.9° F. Of this total heat 855.6 B.t.u. is the latent and 338 B.t.u. the sensible heat of the fluid. When the pressure has fallen to one atmosphere, or 14.7 lb., the total heat is 1147 B.t.u. and the temperature is 212° F., the latent heat is 967 and the sensible 180.

When the pressure has further dropped to one pound absolute, which corresponds to about 28 in. of vacuum, the total heat is found to be 1113.1 B.t.u. and the temperature is 102°. The difference in the amount of energy of the fluid under the three different conditions may be tabulated as follows:

HEAT OF SATURATED STEAM AT DIFFERENT PRESSURES.

Pressure absolute	Volume cu. ft.	Temperature Fahr.	Heat, B. T. U.			Differences	
			Latent	Sensible	Total	B. t. u.	Per cent.
164.7	2.75+	365.9	865.6	338	1193.6	0.0	0.0
14.7	26.6	212	967	180	1147	46.6	3.5
1	335.3	102	1043.1	70	1113.1	33.9	3.0

From the calculation it may be seen that the differences in the total quantity of energy contained in a given quantity of saturated steam at the given pressures are not so very different. This does not represent the actual value of the *available energy,* because it takes no account of the condensation that really takes place and unlocks many additional heat units.

Let us view the pressure-volume curve of a gas expanding, without loss or gain of heat, from 150 lb. down to a fairly good degree of vacuum. As above noted, such a curve will not truly represent the condition of expansion in a steam-engine, but the areas will be approximately those of the indicator card. Considering the part of the area enclosed by the curve above the line of atmospheric pressure as representing work done by the fluid in expanding to that point, and the area below the atmospheric line as proportional to the work done in expanding from atmospheric pressure down to the low-vacuum point, it will be found that the two areas are about equal; or, in other words, just as much energy may be taken from the steam below the atmospheric point as may be gotten above it.

For this reason we find the low-pressure turbine being used to supplement existing non-condensing steam-engine plants. There are a large number of plants in steel mills operating non-condensing; also very many plants operating non-condensing because they are located away from a water-front and it was not advisable to lay long conduits to them for condensing purposes, cooling-towers not having been devised at that time.

The cheapness and efficiency of the steam turbine in utilizing the low-temperature range of steam has opened up a large field of application in plants of this kind. In the case of steel plants where the flow of steam is intermittent the system is augmented by the installation of steam accumulators. The accumulator is a device for storing the heat of steam, either in water or, as in some accumulators, in iron or other metal, taking up the surplus heat when the engine is operating and giving it out when the engine is not operating. On account of the higher efficiency of the low ranges of steam temperature in turbines, and perhaps also because of the slightly higher efficiency of piston engines at high pressures, several engineers have conceived the idea of combining the non-condensing engine with the exhaust steam turbine for initial installation. While this might work out satisfactorily on a steamship, it must be remembered that the problem is different on land from what it is on water. The load on the steamship is constant, and therefore we find triple and quadruplex expansion engines common enough on water. Up to the present time they have not been used on land. The combination scheme, however, has considerable merit from the view-point of economy, and it is not until it is tried out that the relative efficiency can be determined.

The Relation between Engine-Room and School-Room and How to Attain It

The rapidly changing position of the central station in its relation to the isolated plant, coupled with the ability of the central station to supply power very cheaply, has made the operating engineer of the private plant realize within the last few years the need of getting down to first principles by studying power conditions carefully; not alone, however, with the idea of reaching a low cost per unit of output based on some test intended as a comparison with central-station cost. The only aims and methods satisfactory to the isolated engineer are those which insure a continued low maintenance and depreciation during the useful life of the plant. To attain these ends it is better for the engineer to get a good substantial plant giving steady and certain results at a fair ultimate cost to the owner rather than to seek much specializing with the idea of having a chance to make wonderful records.

So much is heard from plant owners and many others that to instal a plant in these advanced and record-breaking times it is necessary to have the newest and most highly developed special machinery in the power plant in order to compete with a company organized and operated as a power-selling business. On the face of it such a statement sounds good and brings many power users to depend on the central station. This statement is correct and absolutely necessary if the client intends to go into the power-selling business too, but for the majority of power users to be swayed by arguments of that kind is generally very unwise. It is just at such a stage where the well-posted engineer must note different operating conditions

that he may clearly judge and just as clearly state his opinions that his employer may be saved from making an unwise move. Again the operating engineer must be just and honest when discussing such a problem with the plant owner, because there are conditions prevailing in many places in which it is a distinct advantage to the owner to use central-station power. In such cases it is well for a man to speak out plain truths.

The power-selling central station is here to stay, because in hundreds of places it is the only method by which the power user can secure a steady and always available supply of power at a reasonable cost. The operating engineers are very much indebted to the central station and ought to study its methods rather than condemn them. The many and various conditions under which power is needed leave room for both central stations and isolated plants.

The central station is in the business of selling power at the greatest profit, and is compelled through the nature of its business to develop a highly specialized power-plant practice. Some of them to-day are undisputed leaders in operating plant. The operating engineer of the isolated plant to succeed must follow in their footsteps and study the individual plant conditions so thoroughly that the isolated plant can to the full take advantage of all its naturally favorable conditions.

Let the operating engineer get into the habit of regarding his boiler plant as the factory of raw products, charging his administration with the cost of raw material used, the plant owner to take the finished product whether it is in the form of electric power, steam or refrigerating, exactly as he would from a central station. Let the isolated power plant remember that the sole business of the plant and organization is:

First.—To produce steam cheaply as possible;

Second.—To reduce the steam consumption to the lowest horse power possible and still give full service to the house; and we will hear more of the real worth of the isolated plant.

To secure justice to the operating engineer's vocation, the men and plant owners ought to organize for the purpose of making it possible to give the operating engineer's vocation the opportunities it deserves. The time seems especially opportune for an extended campaign in behalf of apprenticeship that a true spirit of vocational pride may be fostered in the young men; and secondly for a thorough and practical education. There must and ought to be a closer combination between the schoolroom and engine-room until the apprentice is supplied with a thorough and suitable industrial education, gained during the time he is being trained in the actual practice of his life work. The two are of equal importance. It is only by a close interdependence and relation between the school, and the vocational organization which facilitates the acquirement of practical experience, that it is possible to gain concrete and usable knowledge of the principles which always underlie the actual work done by the apprentice. Such a relationship between work and study, where the school will not waste time to teach the young man unless he has proof from his vocational organization that he is adapted to the work and realizes the need of skill and responsibility, is necessary. And then finally the vocational organization will not give out apprentice certificates to anyone as an engine-room mechanic, whether as a machinery operator, proficient fireman or a finished engineer, unless the school can furnish proof that the applicant has passed the prescribed course of study. Make this work-and-study combination possible in our vocation along prescribed lines and we shall have made a beginning of conditions where complete co-operation is possible between the employer and employee, and there will be no danger of the operating engineer's vocation dying away. In fact, such a combination between a vocation organization in any trade and a suitable training-school carried on simultaneously with the apprenticeship must be established before there will be real reason to expect efficiency in the administration of plants.

The idea of many people that short cuts are possible and that quick routes can be found to the front rank for the young mechanic or the future operating engineer have done untold harm to young men. They find their mistake often when it is too late to correct it. It is wrong for either shop or college to teach and try to fit a young man for a calling for which he is utterly unfit and in which he is bound to make a failure for reasons which generally are plain enough to anyone except himself. It is a waste of time to both. It is for this reason that the proposed National Society of Stationary Engineers asks for two years' actual service before allowing a young man to enter as a regular apprentice either at shop or school. Before the end of two years it will be known if the young man is suitable and can expect to succeed in the vocation if allowed to go further; if not, he can seek more congenial work before it is too late for him to find the kind of work for which he is best equipped.

The proposed N. S. O. E. should have as its aim not only to make its apprenticeship members operating engineers, but to make all of them well-trained and conscientious machinery operators and proficient firemen that the various plants may be supplied with a responsible and reliable set of plant operators, who, as such, can and will produce results and are known as engine-room mechanics. It is from this class that the successful operating engineers will come.

Boiler-Room Economy

The increasing attention given matters affecting fuel economy is apparent from the correspondence and articles on this subject appearing in the technical press. That the matter is of extreme importance is also evidenced by tests already made and now under way, under the management of the United States Geological Survey.

Many central station managers and engineers have spent considerable time in studying the problem, but it is also true that plants without number are burning coal inefficiently, resulting in a consequent higher operating cost per unit output. Especially is this true in the smaller plants in the South, where negro labor only is available. While some of the more intelligent of this race appear to understand fairly well the connection between proper draft regulation and economical burning of coal, the greater number run at all loads with dampers wide open and a heavy fire, resulting in a much larger consumption of coal than necessary.

Where the capacity of the plant will not justify the installation of stokers, the best method of procedure is for the engineer to experiment with the thickness of fire and damper opening at the various loads until the most economical arrangement can be determined. Some means can then be had to mark the various positions of the damper, so that the fireman can himself regulate the draft to suit the load. This method of procedure in a certain case resulted in reducing the consumption during 24 hours from 20 tons to less than 17 tons.

It is true also that some coals are sold more on their reputation than on their actual burning qualities, hence the necessity, now fortunately recognized by many central station men, of buying coal on a B. T. U. basis, a bonus being paid for a calorific value over a certain amount, and a rebate being made by the coal company should the B. T. U.'s per pound of coal fall below the arbitrary standard set for that particular case.

The Limitations of Party Transformer Distribution

J. FRANK MARTIN

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While much has been said in central-station circles about the economy effected by party transformer distribution, very little attention has been given to the minor engineering principles and details, which, when carefully considered, will promote the highest operating efficiency in the apparatus employed.

Briefly, the features which particularly recommend this practice are widely known as the large saving in first cost, and especially the increase in efficiency, which is brought about by the substitution of large transformers having small losses for a multiplicity of smaller ones having a comparatively higher loss. A large decrease in the diversity factor, which is a result effected when a number of installations, each having a different characteristic, are brought together in one group, adds to both results. Under the most favorable condition, which is the substitution of a party transformer for individual installations in a thickly populated district, the saving in the investment reaches a value of 60 per cent., and the all-day efficiency is increased 320 per cent. If this substitution is made by replacing transformers of an obsolete type, using those of modern design, this saving will reach a value considerably higher.

The mechanical construction, whether the installation is overhead or underground, is governed largely by the electrical design, and may be assumed to follow certain definite lines in either case. For this reason the discussion will be confined to the electrical problems which would be considered in the order of the importance of each as follows:

(1) Ratio between transformer capacity and connected load;

(2) Capacity and range of secondary mains;

(3) Balancing and distribution of the load on the secondary mains.

Investigation shows that the average maximum running load on a large group of residence installations equals 30 per cent. of the connected load. This proportion varies considerably with the selling price of current, the size of the installation, the r lative size of each installation to the group of which it is a member and the environment and personality of the consumer who controls the installation. The ratio is higher for small dwellings and apartment houses than for large homes, due to the fact that the latter installation is restricted to limited spaces and frequent and more constant use.

For "commercial loads," consisting of small stores, offices and miscellaneous business houses, this ratio has a value of about 40 per cent. for five days of the week, rising as high as 75 per cent. on Saturday nights. In every case this ratio varies in inverse proportion to the number of members in a group.

Fig. 1 gives the characteristic performance of a party transformer having 70 residence installations connected. It represents the normal load and load period for every day in the year and the maximum and minimum load at any time will not vary more than 5 per cent. from the values given.

When the investigation is carried down to the performance of each individual installation it is found that there are periods when this proportion

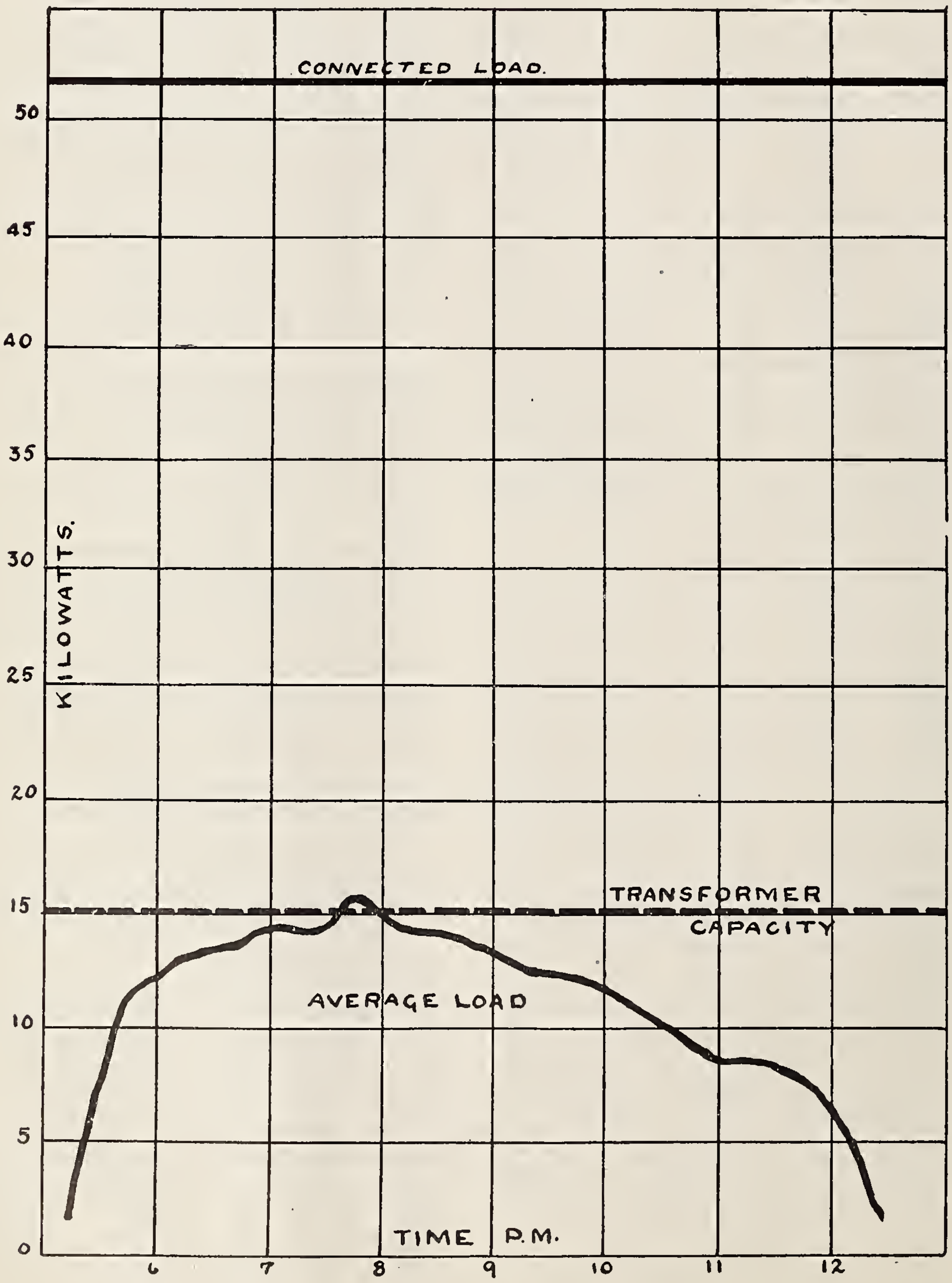


FIG. 1

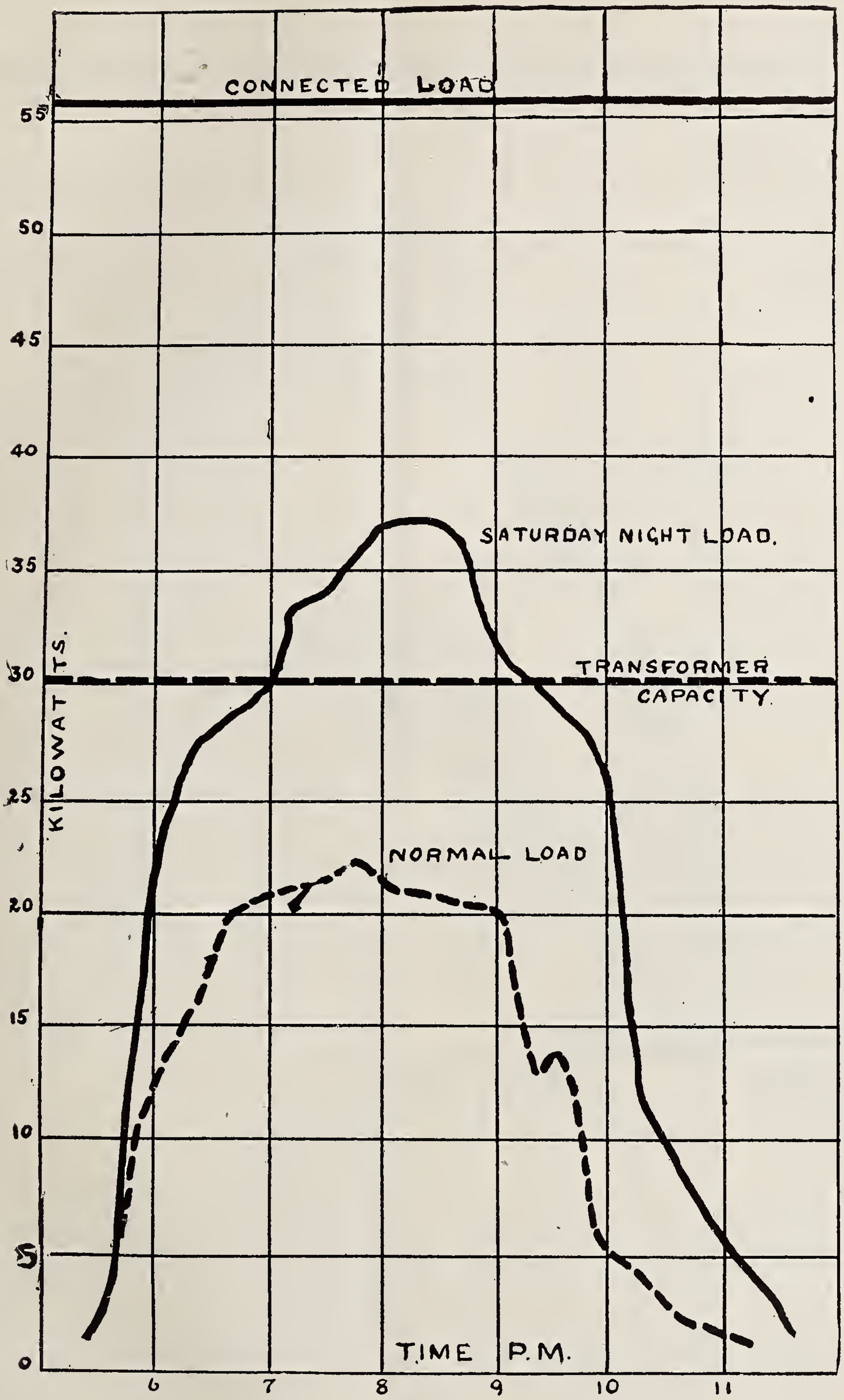


FIG. 2

does not hold good. There are times when the consumer will use from 50 to 75 per cent. of the total lamps, but these periods are infrequent, and in a large group a very small percentage of these periods are coincident.

Fig. 2 shows the performance of an installation having a load of small stores, offices, cafés, signs and a few residences. The broken line represents the load for every day except Saturday night, which is shown by the solid line. This performance is typical of this class of service, and the layout of this particular installation is considered ideal. For a period of two hours each week the transformer is subjected to an overload of 25 per cent., but this is not sufficient to give an objectionable voltage regulation or cause deterioration in the transformer.

In Fig. 3 the load curve shown in Fig. 1 is extended to cover 24 hours, and over it in a broken line is plotted the transformer capacity showing a mean resultant of the manufacturers' guaranteed overload performance. The dotted line A shows the dropping off in load during the summer months, caused by a longer daylight period. This change follows the variation of atmospheric temperature from season to season very closely, and when combined with the overload performance, affords an opportunity for increasing the all-day efficiency, which is seldom taken advantage of in central-station practice, due to certain limitations set by increased voltage regulation and unbalancing of load on three-wire distribution.

In Fig. 4 the results of the investigation of the several types of service are plotted in a chart for determining the proper ratio of the transformer capacity to the connected load. The transformer capacity in percentage of connected load is plotted against the number of installations connected. Curve A is for large business establishments and a strictly commercial load. B is for miscellaneous loads, consisting of small business houses and residences grouped, a condition which generally exists at certain points in suburban districts. The double curve C applies to residence loads. The top line is for small installations, moderate-sized dwellings and apartment houses, while the lower line is for large houses having a large number of lamps. For this character of service it can safely be assumed that if the ratio falls within the shaded area between the lines the transformer will operate satisfactorily.

The above data should also be applied in designing the mains for distribution. The first question arising is along what lines shall they be developed? This problem is very simple if it is only a matter of substitution. The installation can be designed for an easily-determined characteristic shown by the installations being replaced. On the other hand, if the installation is to be made in a sparsely-populated district, or when a new company begins operation, it is preferable to install the lines covering a comparatively large area, and of such capacity as required by a fully-developed district. As the load is gradually increased by the building up of the locality or as the result of active business-getting methods, these mains should be cut in sections and additional transformers should be installed. It is also important that some definite specification, such as making the losses in the mains equal to that of the transformer for a predetermined radius from the center of distribution, be followed. Some such rule should be strictly adhered to, since it is necessary that the regulation of each unit or group of installations of a system have a similar characteristic.

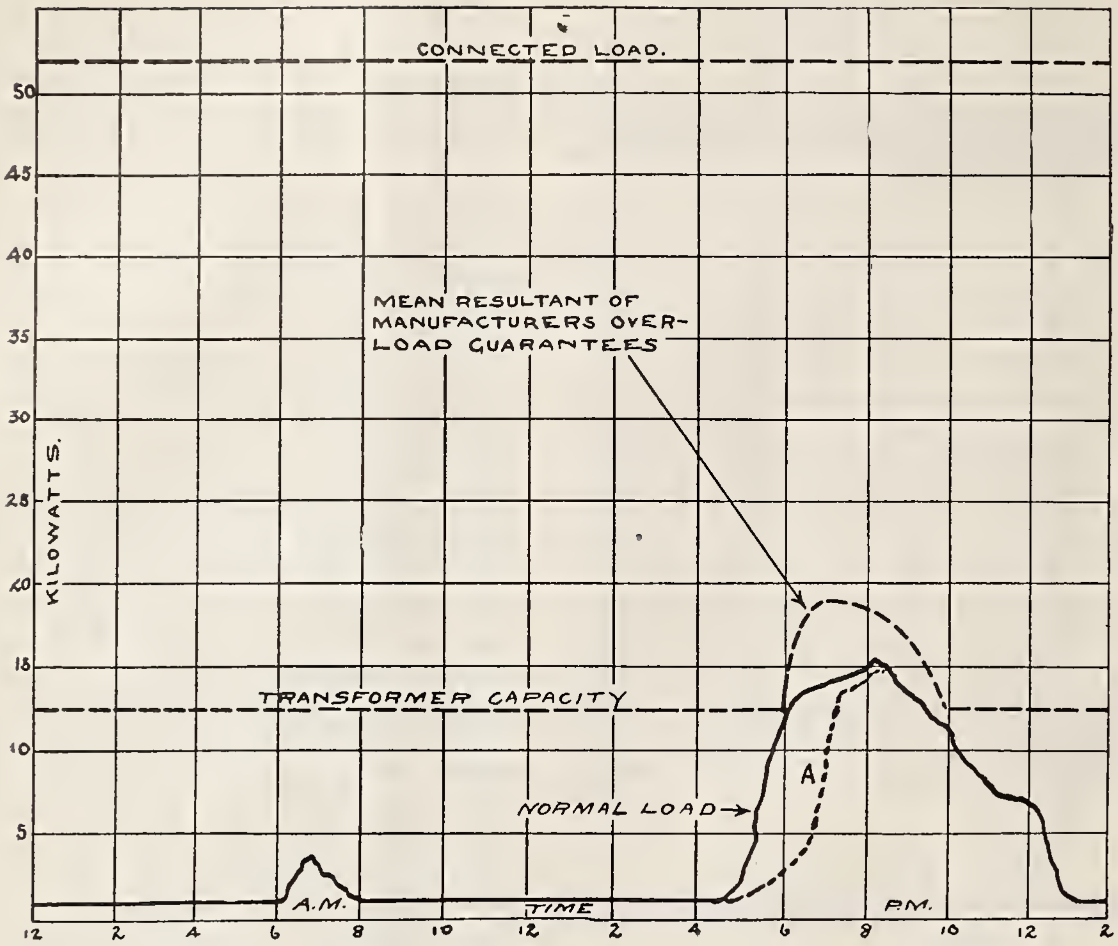


FIG. 3

The question arises here of operating transformers in parallel when several hundred feet apart together with the mains as a network. This practice promotes voltage regulation and allows a still lower reduction of the ratio between the transformer and its connected load, but unless the transformers are of the same size and make, unless reliable cut-outs are used at all interconnecting points, and the load is evenly distributed over the whole area covered by the net-work, interruption of service will be increased. The cut-outs serve in the capacity of isolating any section developing a fault, and with the attention necessary to guarantee successful operation, it is a question whether the benefits derived warrant the extra expense.

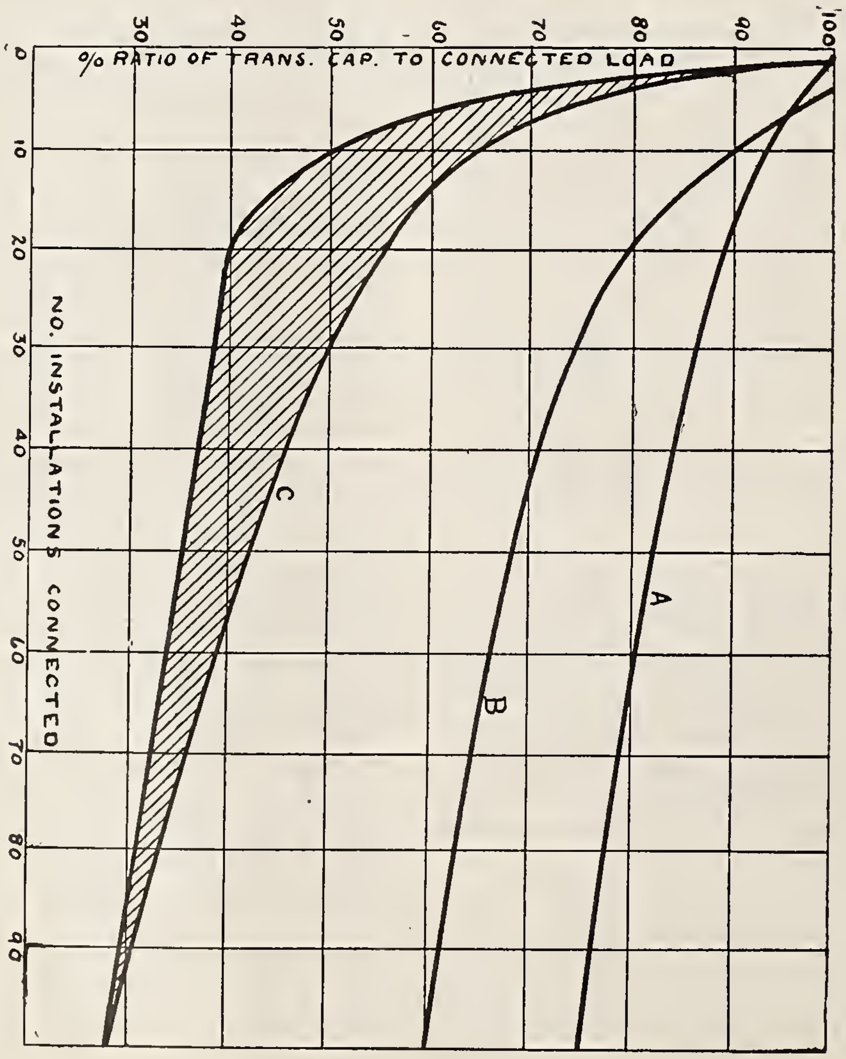


FIG. 4

The most difficult problem arising in connection with the distribution system is the balancing of the load on the three or four wires, depending upon whether the three-wire single-phase or four-wire three-phase principle of distribution is used. To work the copper at the highest efficiency it is necessary that the current in the neutral wire be at a minimum. Balancing of the load does not simply mean the placing of a given number of installations having the same amount of load against each other, but the characteristic performance of each installation must be considered individually. Here, again, the ratio of the running load to the connected load comes into account. Each installation resolves into a special problem requiring a careful study of the effects of various conditions in supply and demand. An apartment house having 100 lamps cannot be balanced against a residence having the same number, neither can the load of a saloon, drug store or department store be placed against an office building. Commercial loads show an individual characteristic to a more marked degree than residence loads. Fig. 5 shows the current in each outside conductor of the three-wire party-transformer installation represented in Fig. 2. The lines A_1 and B_1 indicate the maximum load of Saturday night, while A_2 and B_2 represent the normal load. The shaded area represents the unbalancing of the load in each case. This current reaches a high value, resulting in an objectionable overload on one-half of the transformer and increasing the losses in the mains to such an extent that poor voltage regulation is caused at distant points. This condition exists, although the connected load is almost exactly balanced, and is caused by all the load on one side being saloons and large stores, while the other side has a load of residences and small shops.

The connection of motors and all installations having a heavy intermittent load should be avoided. Churches, moving-picture theaters and flashing signs are representative of this class of service; the load is generally large as compared with that of other installations in the immediate vicinity, and the performance is such that an unbalancing effect and an objectionable voltage regulation cannot be avoided.

The most practical solution to the problem of balancing the load is di-

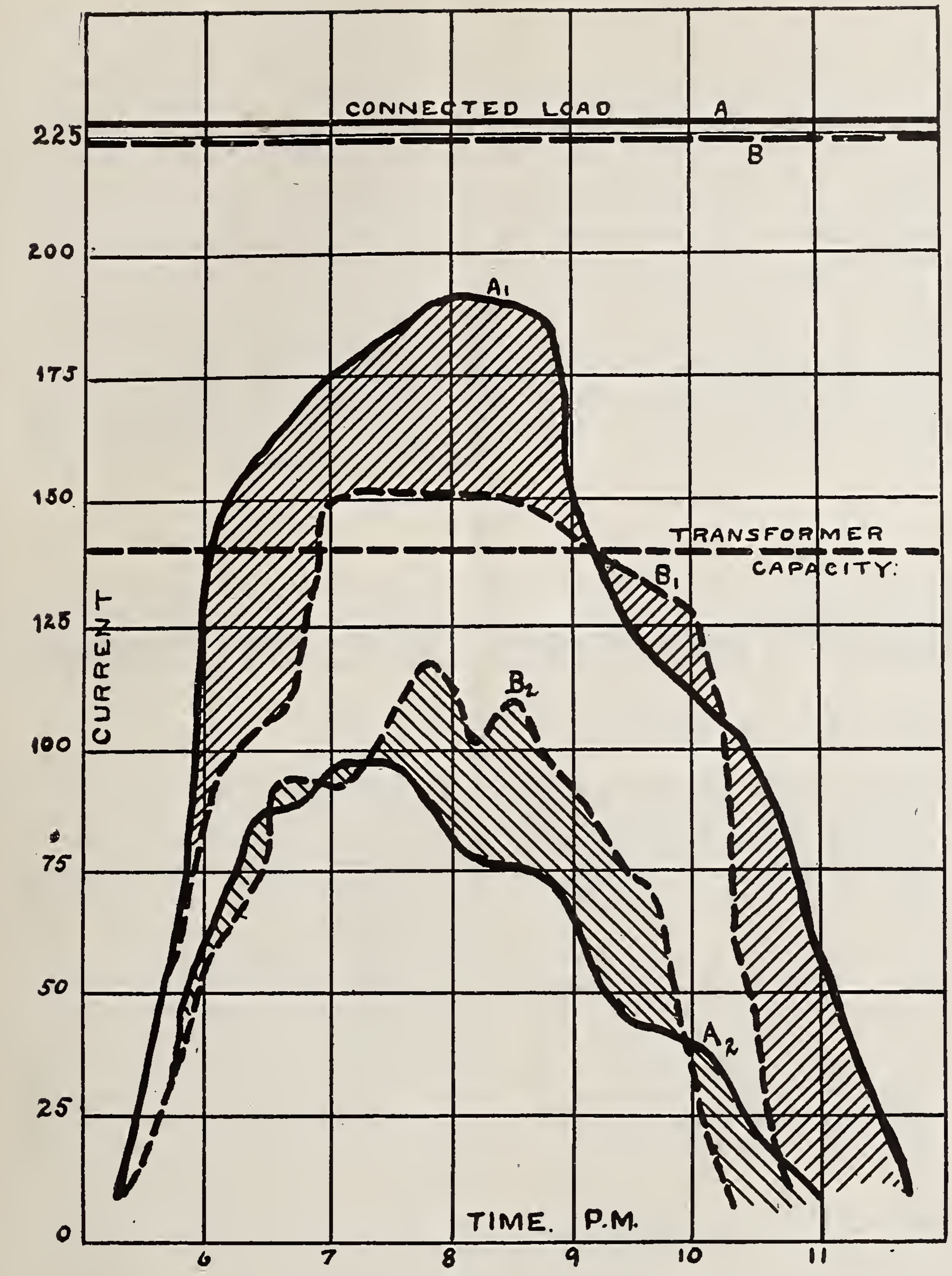


FIG. 5

vision and subdivision of each individual installation, and the remedy is three-wire distribution down to the consumer's panel-board or the several panel-boards of a large installation. This practice is particularly desirable in business districts, where the diversity factor has the greatest range.

One central-station manager has said that, "You must know a consumer's personal history from his cradle up to proportion a system so that it will give him service at the highest efficiency." The problem is not so hopeless as this. A reasonable amount of attention to details and simple records will often give remarkable results.

Water Treatment by Electricity

At the recent annual meeting of the American Railway Engineering and Maintenance of Way Association, J. L. Campbell, engineer of maintenance of way of the El Paso & Southwestern system, presented a paper dealing with some experiments in reducing the hardness of water by electricity. The treatment consisted in submerging aluminum or iron plates in the water to be treated, and passing electrical currents through the same. It has been demonstrated that, with clean plates satisfactory results are secured, except in the matter of cost, which is very high. The experiments have not extended far enough to be able to submit definite figures of cost. It appears that on account of the quality of the water, the cost of the electrical treatment would be justified, provided the efficiency of the treatment could be maintained. It is found, however, that the plates incrust quite rapidly, and the efficiency of the treatment quickly falls off after the plant has been in operation for a few days, beginning with clean plates.

As an index of the results obtained so far, the hardness of the water at Alamogordo is 40 grains per gallon. During the first three or four days of the treatment, this hardness was reduced to seven grains per gallon. As the operation was continued, and the plates incrusted, the efficiency fell off until at the end of a week or ten days the hardness of the water had risen to 20 grains per gallon, at the end of the same periods of treatment which, in the beginning, reduced the hardness to seven grains. Iron plates give practically the same results.

At Pastura the water has a hardness of 180 grains per gallon, and at the present writing this has been readily reduced by iron plates to a hardness of 90, at which point the reduction has stopped. It appears, however, that by increasing the time and intensity of the treatment, it will be possible to still further reduce this, but these experiments are not yet completed.

Outside the question of cost, the problem appears to be one of cleaning the incrustation from the plates at frequent intervals after a given plant has been placed in operation. In an experimental plant having a capacity of 125,000 gallons of water treated in 24 hours, being erected at Alamagordo, there will be 27,000 square feet of plate, or 54,000 square feet of plate surface. These plates are three feet square, and the experiments to date indicate that they will have to be cleaned at the rate of one plate per minute during the operation of the plant in order to keep the latter up to its full efficiency. Evidently this would have to be done by machinery, and apparently this is a point that may render the process impracticable.

It has been demonstrated that, with clean plates, the hardness of the water can be reduced very much below that possible by the use of lime and soda ash, on account of the trouble of foaming when the latter treatment is carried to the excess required for these very bad waters. The electrical treatment does not increase the priming tendency of the water; in fact, it has a slightly beneficial effect.

In the reduction of the water at Alamogordo, from 40 grains to 7 grains per gallon of incrusting solids, the power required was 7 electric horse-power-hours per 1000 gallons of water treated, the potential of the

electric current being from 100 to 125 volts.

In the experiment at Pastura, the power required was just double the above.

The experimental plant at Alamogordo consists of three vats or tanks, 3 feet deep, 5 feet wide, and 80 feet long, each divided into 25 compartments, in which the 3 by 3 foot plates were set on edge, and spaced one inch center to center, all the sections in each vat and the several vats being connected by proper electrical wiring. The vats are then filled with water and the electrical current turned on.

At one end of the vats there is a storage or supply tank, and at the other a precipitating tank from which the water is pumped through a filter to the railroad service tank. The perfectly treated water is a clear, limpid and very pleasant drinking water.

Apart from the apparent physical impracticability of the constant, removal, cleaning and replacement of the iron or aluminum plates necessitated by the requirements of constant cleaning, this process would appear to be the most efficient of any system of treatment under the exceptional conditions obtaining on the eastern division of the Southwestern.

For the treatment of the water at Alamogordo above specified, it appears that the loss of weight of the aluminum plates is at the rate of about ¾ pound to 1000 gallons of water treated. The experiments with the iron plates have not proceeded far enough to determine the loss from them. The incrustation of the plates is similar in a general way to the incrusting of locomotive boiler tubes, except that the scale is not nearly so hard, but still requires the application of a scraper to remove it.

The sludge precipitated from the treatment is of very fine flocculent matter of milky color.

Foundations and the Use of Concrete

By GEO. W. MARTIN

THE general statement may safely be made that in every power plant or manufactory laid down in recent years the wall footings and machine foundations have been of concrete. This material has now become an indispensable element in the construction of the modern plant, and it will be the writer's aim to bring out some of its more important characteristics, taking up first the discussion of foundations in general.

In designing the foundations for any structure, whether a building or an engine, the first consideration is the nature of the soil on which the foundation is to be built up. Naturally a hard clay will bear more per square foot than a soft clay, and rock more than hard clay. In cases where it is not important to have the exact bearing capacity of the soil, a close enough approximation may be obtained by judging the hardness of the soil during the excavation and consulting the tables given in hand-books, such as Kidde's. But experience and good judgment are necessary to use the information in these tables to good advantage.

Where it is necessary to obtain an exact estimate of the bearing power of a soil, however, an actual test must be made, either by applying pressure to a definite area or, if piles are to be used, by driving a test pile. In the method of applying pressure, a piece of timber 12 by 12 in. is held by guys vertically, a platform being provided to hold the weights making up the load. The bottom of the timber is set in a hole about three feet deep, 18 in. square at the top and 14 at the bottom. Two stakes are driven, one on each side of the timber, several feet away, and a piece of fish-line or fine wire is stretched between them, almost touching one side of the timber. At this point on the timber a scale may be fastened so that any sinkage of the timber as the load is added may be noted. Another method of obtaining the sinkage is by means of an engineer's level. When the timber sinks the load applied may be considered the ultimate bearing capacity of the soil, and from one-fifth to one-half of this is usually taken as the safe working load.

In the method of testing with piles, the pile is driven in the usual way, and on the last blow the fall of the hammer and the penetration of the pile are taken. The safe load is obtained by using these values in the following formula:

$$L = \frac{2\,W\,h}{S + 1}$$

L = safe load.
W = weight of hammer in tons.
h = fall of hammer in feet.
S = penetration of pile in inches.

In testing a soil of hard clay the test may give the following results:

W = 1800 lb. = 0.9 ton.
h = 26 ft.
S = 2 in.

L then becomes $\frac{2 \times 0.9 \times 26}{S + 1} =$ 15.6 tons.

Another formula for obtaining the safe bearing load of a pile is that given by Sutcliffe, as follows:

$$\text{Safe load} = \frac{W\,H}{8\,D}$$

W = weight of hammer = 0.9 ton.
H = fall of hammer = 312 in.
D = penetration of pile = 2 in.

The safe load then will be 17.5 tons, which agrees closely with the result obtained by the first formula.

By closely watching the piles when driven an experienced man can tell very closely how much they will bear. A very small penetration, say one-half inch or one inch, with a long fall of the hammer, may generally be considered as good evidence that a pile is splintering at the point instead of penetrating farther. This, of course, is to be avoided, and it may be put down as a fairly good indication that when a pile drives from two to three inches on a 25- to 30-ft. fall it has reached the limit before splintering.

The length of the pile will, of course, depend on how far below the surface ground of sufficient hardness to hold the pile is obtained. In some of the soft alluvial deposits in the South it has been necessary to splice two 30-ft. piles before a two-inch penetration on the last blow could be obtained. The minimum spacing of the piles should be about 2.5 or 3 ft., or something more than enough to prevent the breaking up of the ground.

When soft ground is encountered, necessitating the use of piles, an excellent foundation is obtained by placing a layer of concrete over the piles. Enough of each pile is left above ground so that it may be sawed off one foot above ground. A layer of concrete 18 in. thick is then placed over and around the piles, the thickness above the top, of course, being six inches. When the foundation requires it, reenforcement may be placed on this

layer, the bars being on 12-in. centers, and another layer of concrete is placed over them. Where the bars lap, if they are not long enough to extend the full length of the foundation, fully two inches should be left between the parts overlapping to allow the concrete to grip the bars all around. If the bars cross at right angles they may be in close contact.

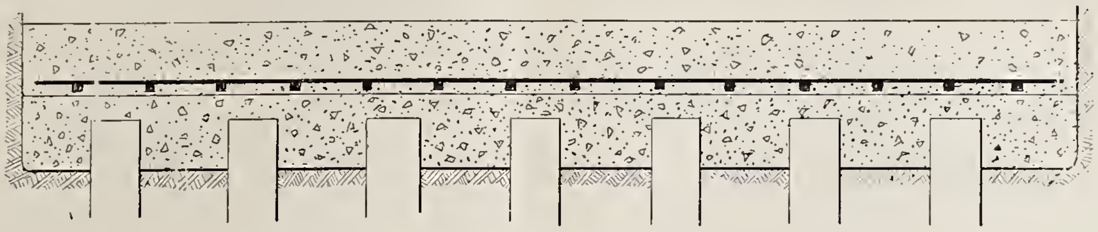


FIG. 1

Fig. 1 shows a section of a foundation built of piles and re-enforced concrete and Fig. 2 shows how the bars should be spaced.

SPECIFICATIONS FOR CEMENT.

It is important to establish some standard up to which the cement to be used must measure before it can be accepted for use in the work proposed. The characteristics of cement usually appearing in specifications are specific gravity, fineness, time of setting, tensile strength, constancy of volume and test by sulphuric acid. The quality of cement for ordinary work, however, can be determined by making only three of these tests, namely, time of setting, constancy of volume and tensile strength, so that while in the following all the characteristics are dealt with, the three just named are treated of more fully.

The *specific gravity* of the cement, thoroughly dried at 100° C., shall not be less than 3.1.

Fineness.—The cement shall leave by weight a residue of not more than 8 per cent. on the No. 100 and not more than 25 per cent. on the No. 200 sieve.

Time of Setting.—The cement shall develop initial set in not less than 30 min., but must develop hard set in not less than one hour nor more than 10 hours. An approximate method of determining the time of setting is to press gently on the cement with the finger-nail, ability to bear a slight pressure indicating initial set and resistance to greater pressure indicating final or hard set. For accurate results, however, test wires or "Gilmore needles" are used. One of these consists of a steel needle one-twelfth inch in diameter, loaded with a quarter-pound weight, the second needle being one-twenty-fourth inch in diameter and loaded with a one-pound weight. The quarter-pound needle is used for the initial set test and the one-pound needle for the hard-set test.

In making these tests a "pat" three inches in diameter, one-half inch thick in the center and tapering to a thin edge is made of neat cement. When the cement has set sufficiently to bear the weight of the quarter-pound needle initial set has begun, and when able to bear the one-pound needle hard set has begun. It must also be borne in mind that the results will be influenced by such details as the quantity, temperature and composition of the water used in mixing, the amount of mixing, the temperature of the cement and the temperature and character of the material on which the pat is placed after molding. It is therefore important in making comparative tests of cement to have the various conditions of the separate tests as near alike as possible.

Constancy of Volume.—Pats of neat cement should be kept in moist air (covered with a wet cloth) for a period of 24 hr. A pat is then kept in air at normal temperature and observed at intervals for at least 28 days. Another pat is kept in water maintained as near 70° F. as practicable and observed at intervals for 28 days. A third pat is exposed in any convenient way in an atmosphere of steam above boiling water in a loosely closed vessel for five hours. These pats, to satisfactorily pass the requirements, must remain firm and hard and show no sign of distortion, checking, cracking or disintegrating.

The pat in water should be examined daily to see if it becomes distorted or if cracks appear at the edge. Sometimes when the tendency to crack is caused by the presence of too much unslaked lime this will disappear with time. If the pat exposed in air shows any yellowish blotches a poor quality of cement is indicated. Portland cements (those manufactured from limestone and clay with other materials varying with the brand) have a bluish-gray color. Natural cements (made from limestone more or less impure in which the necessary ingredients for cement are found in nature) are light or dark, according to the character of the work of which they are made.

In the boiling test the pat is placed in water at ordinary temperature and the water heated gradually to the boiling point. Should a tendency to crack be caused by too much unslaked lime, as before mentioned, the cement should be spread out in a perfectly dry place for a few days and the tests repeated.

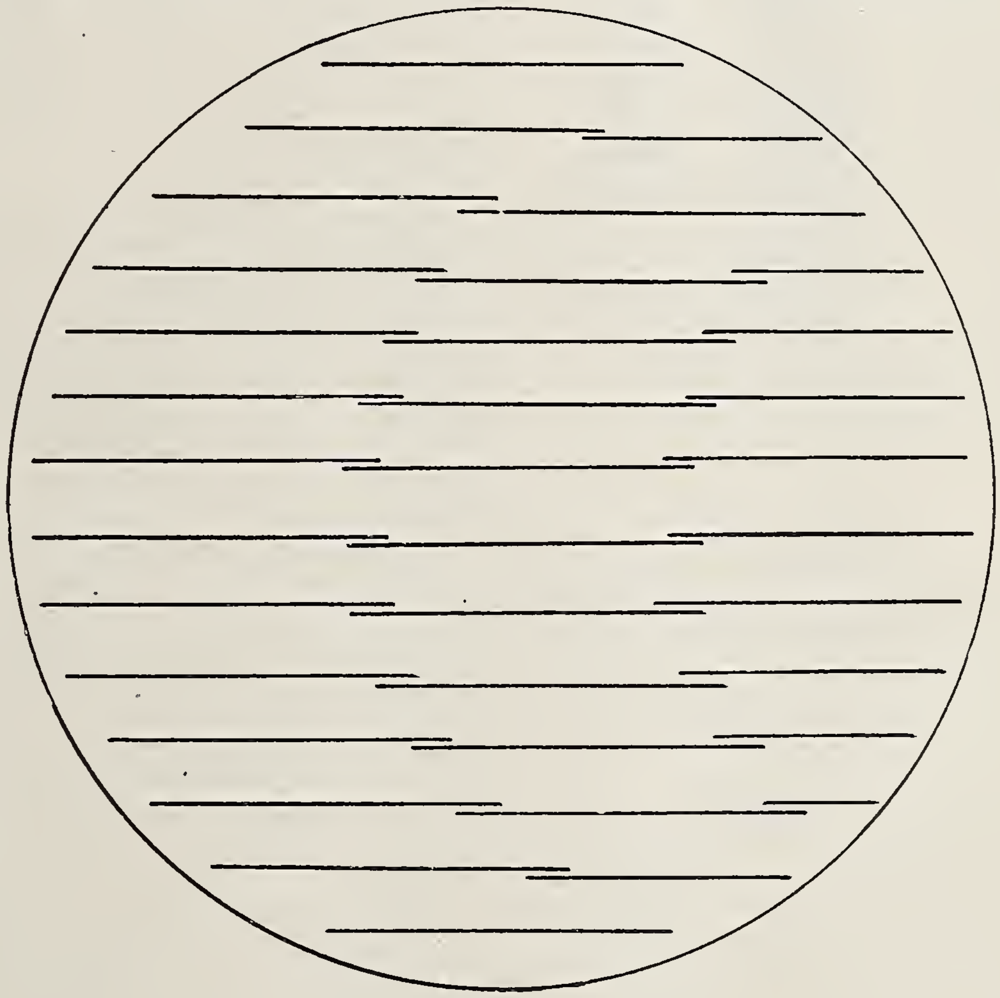


FIG. 2

Tensile Strength.—The minimum requirements for tensile strength for briquettes one inch square in section shall be within the following limits

and shall show no retrogression in strength within the periods specified:

NEAT CEMENT.

Age, 24 hr. in moist air; strength, 150-200 lb.

Age, 7 days (1 day in moist air, 6 days in water); strength, 450-550 lb.

Age, 28 days (1 day in moist air, 27 days in water); strength, 550-650 lb.

ONE PART CEMENT, THREE PARTS SAND.

Age, 7 days (1 day in moist air, 6 days in water; strength, 150-200 lb.

Age, 28 days (1 day in moist air, 27 days in water); strength 200-300 lb.

Books on concrete agree that the results of briquette tests are largely a matter of the personal equation, different results being obtained with the same cement by different persons. Methods of mixing and pressing into the molds are largely responsible for these differences. Even in the methods of the same operator, however, there is likely at first to be such variation as to cause appreciable differences in the results obtained. As one grows in experience,

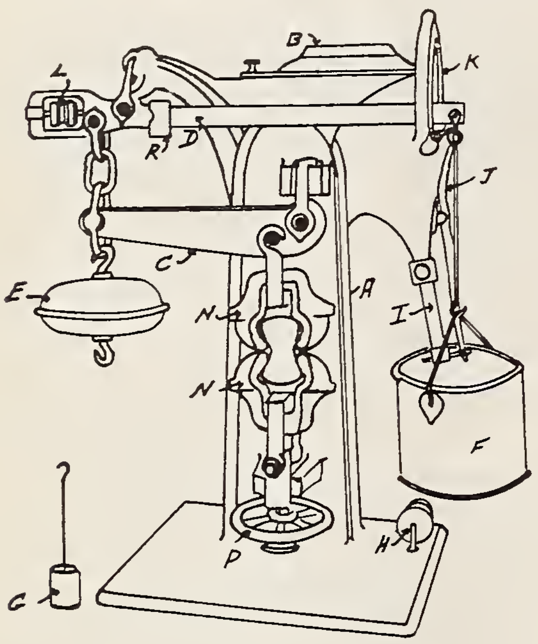


FIG. 3

however, the variations grow less; for example, neat briquettes tested by the writer in the early days of his experience showed results varying from 550 to 350 lb., while some resent tests of sand and cement briquettes, three to one, showed a variation of about five pounds in seven briquettes.

The amount of water added to the cement will affect the results, so it is important to keep the amount constant. Recent tests by the writer to determine the effect of varying percentages of water in the mixture gave the following results:

No. of sample.	Cement. oz.	Water. oz.	% water. (approx.)	Broke at. lb.
1	10	3	30	375
2	10	2.5	25	385
3	10	2	20	460
4	10	1.5	15	508

Sample No. 1 was very sloppy, making any tamping impossible. Between this and sample No. 2 there seemed to be little difference in the working. Sample No. 3 could be lightly tamped, while it was necessary to tamp sample No. 4 quite solidly to make the mass compact, the mortar being unable to hold together without it.

In making briquettes the best way to mix the neat cement with water is to place it on a glass plate in a ring and pour the water into the ring and turn the cement into the water. If the water is added gradually the cement will take up of a greater amount of it and not always in the same proportion, causing the results to vary. If there is any suspicion of air bubbles in the cement after it is pressed in the mold they may be brought to the surface by taking up the mold on a small glass plate and jarring it lightly on the edge of a table.

The briquette testing machine which the writer has used is shown in outline in Fig. 3. The sequence of operations is as follows: Hang the cup *F* on the end of the beam *D*. See that the poise *R* is at the zero mark, and balance the beam by turning the ball *L*. Fill the hopper *B* with fine shot. Place the briquette in the clamps *W. W.*

In placing the briquette in the clamps it should be carefully adjusted so that the four rollers which grip the briquette will be parallel; otherwise a side strain will be exerted on the briquette and cause it to break between the jaws of the clamps and not at the smallest section.

Tighten the hand wheel *P* enough to cause the beam *D* to rise to the stop *K*. Just enough pressure should be placed on the beam to hold it against the stop. Then open the automatic valve *J* and allow the shot to run into the cup *F*. Where the spout joins the shot reservoir a small valve is provided to regulate the flow of shot. When the briquette breaks the beam *D* drops and closes the valve *J*, thus stopping the flow of shot. Then remove the cup and hang it on the hook under the ball *E*. Hang the counterpoise *G* where the cup *F* first hung. Then by sliding the poise *R* on the beam *D* and, if necessary, adding the weights *H* to the counterpoise *G*, the reading on *D* will give the number of pounds per square inch at which the briquette broke.

Sometimes the briquette will stretch so that the beam *D* will fall and shut off the flow of shot before the briquette breaks. The beam should then be raised against the stop and the hand wheel turned enough to hold the beam suspended. The flow of shot is again started as before.

SAND.

Sand, whether for cement mortar or for concrete, should be clean, coarse, sharp and free from dirt, loam and clay. The requirement for cleanness and freedom from dirt, etc., is necessary because the cement will not adhere to these yielding materials, which prevent the formation of a solid mass. Also when the sand is coarse and sharp the irregular particles not only hold the cement better, but also pack more closely, leaving fewer voids to be filled with the cement. In connection with this it may be said that a sand with particles varying in size will make better concrete, as the smaller particles will fill the voids between the larger particles.

STONE.

The specifications regarding stone usually require that it shall be of trap rock, hard limestone or other suitable kind. The size may vary from that required to pass through a three-fourth-inch ring to the two-inch size, according to the size of the work. It is usual to specify but one size for a particular job, but, as with sand, varying sizes of stone in the concrete will diminish the voids to be filled with the sand and cement and make a more solid mass. The reason that this idea

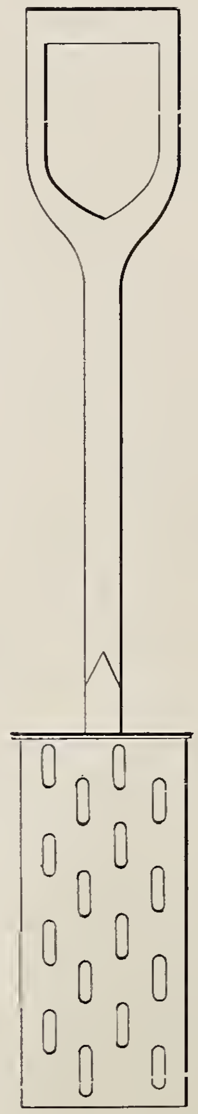


FIG. 4

is not carried out in practice is doubtless due to the extra labor required in mixing the stone of various sizes, as stone is usually sold in lots of one size.

PROPORTIONS.

The proportions most widely used in mixing concrete are one of cement,

three of sand and five of rock. In theory, the sand is supposed to fill the voids in the rock and the cement to fill the voids in the sand. Acting under this theory then, if the proportions of one, three and five were correct for rock of two-inch size, rock of smaller size would contain less voids and would therefore require less sand. In practice, however, the proportions remain the same for the various sizes ordinarily in use in structural or foundation work.

In measuring the proportions, a barrowful is usually taken as the unit of measure, so that a batch would be made up of one barrow of cement, three barrows of sand and five barrows of stone.

When the mixer is placed in such a location that wheeling barrows of the raw material up an incline is necessary, close inspection must be exercised, as the workmen will show a tendency to fill the barrows less than the proper amount in order to lighten the load.

MIXING AND PLACING.

With regard to machine mixing, it may be said that it matters little in what order the sand, cement and stone are placed in the mixer, as the construction of any good mixer serves to thoroughly combine the three in a very short time. In hand mixing, however, a certain cycle of operations is necessary. On a suitable mixing-board the sand is first spread, then the cement is placed on top and leveled off. The two layers are then turned until the whole presents a uniform color, when sufficient water is added to bring it to the desired consistency. The mixture is then leveled off and wet stone added, the whole being turned over until the stone is thoroughly incorporated in the mass.

In placing the concrete the ideal way would be to chute it directly to the place desired. This, however, is seldom possible in practice, some fall from the end of the chute being unavoidable. The greater the fall, the greater is the chance for the stone and the cement and sand to separate; hence the necessity for keeping the mass together on its way from the mixer to the form.

In order to obtain a smooth surface on the concrete it is necessary to work a spade between the wet concrete and the form to push back the rock and allow the mortar to come into contact with the form. The best implement for this purpose may be made from the so-called tiling-spade or "sharpshooter," with holes cut in the blade as shown in Fig. 4. These holes will allow the mortar to run through, while the rock is held away from the form. Some concrete workers seek to accomplish the same end by chuting the concrete against the sides of the form so that the rock will rebound and the mortar remain close to the form. This has the disadvantage, however, that the mortar will be splashed over the form, the wood will absorb the moisture, the mortar will set, and when the form is removed the surface of the concrete will be pockmarked, because the splashings have kept the wet concrete away from the form.

Report of the Western Electric Co.

According to a report of the Western Electric Co., the business in February ran at the rate of about $45,000,000 a year. The business of the Western Electric Co. with the telephone companies has shown a steady increase from month to month, but a large part of the improvement continues to lie with the machinery department. As in January, a number of the Hawthorne shops are operating at full capacity and the electric-light machinery shops are operating overtime. The most recent large order of importance was for two generators totaling 1800 h.p. for the Albany shops of the New York Central. At the present time the company has somewhat over 16,000 employees on its payrolls, and the number is being increased gradually.

Lamp Signals in the Boiler-Room

It is most important in modern plants equipped with automatic apparatus of an auxiliary character to know that things are going right when no one is in sight of the machinery. In some cases, for example, says the Electrical Review, of London, it is necessary to operate fans on the forced draught system at varying speeds, depending upon the requirements of the load. In one station visited the boiler-room was about 300 ft. long, and only a part of the boilers were provided with forced draught, the rest depending upon the natural air supply furnished by a large and high chimney.

Under ordinary conditions of load the natural draught boilers were operated, but when the demands upon the station increased beyond the economical capacity of the furnaces and water-heating surfaces, the additional boilers were brought into use, calling for the operation of the fans by small slow-speed horizontal engines exhausting into the feed-water heating system. It was desirable in this boiler-room to cut down the labor cost as much as possible, and on account of the great length of the plant it was found possible to reduce the supervision of the machinery by installing a simple lamp circuit on each fan, fed on a 110-volt line. At each turn of the fan a contact was made in the lamp circuit, and the position of the lamp for each fan above the boiler-room floor enabled the force at the other end of the room, and particularly the boiler-room foreman, to see how the fan speed was varying, by counting the flashes corresponding to the revolutions.

Although in many plants the feed pumps and condensing equipment are situated under the eye of an operating engineer who spends most of his time in their supervision, it is sometimes desirable to install a lamp-signal circuit which will indicate the number of pump strokes in a given time. A miniature lamp on a reliable battery circuit, or run by power-house current through a suitable resistence to cut down the voltage, can be fitted up with little trouble and cost, and arranged to indicate either in the chief engineer's office or elsewhere the operation of the pumps throughout the entire period of plant operation. In the same way, an indicating lamp circuit is useful when connected with the motor driving the coal crusher or conveyer. The cost of operating such a circuit is a small matter compared with the convenience of knowing just what is taking place in the less accessible portions of the station.

Electric Headlights in North Carolina

The Legislature of North Carolina has passed a law requiring electric headlights to be used on all road locomotives within four years. The law specifies an "electric or power headlight" of at least 1500 c.p., measured without the aid of the reflector. Of the engines of any company not now equipped, one-fourth must have the lights by April 1, 1910; one-fourth the next year; one-fourth the next, and all by April 1, 1913. The law does not apply to engines regularly used for switching, nor to those used only in the daytime, nor to engines going to shops for repairs. An engine may finish its trip notwithstanding the unavoidable disablement of its headlight, if the light was in good condition when the engine started out. A further exception is made of North Carolina roads "independently owned" operating 125 miles or less, and of roads outside the State which operate only 100 miles in North Carolina; further, the corporation commission, in its discretion, may make exceptions. Violation of the law is a misdemeanor.

The March number of *Graphite*, the publication of the Joseph Dixon Crucible Co., of Jersey City, N. J., contains much that is of interest. Chapter X of the article by W. H. Wakeman, on "Preventing Corrosion of Steam Machinery," with other features, make the pamphlet worth having.

Curtis Steam Turbines for Large Power Stations

By W. E. MILLER

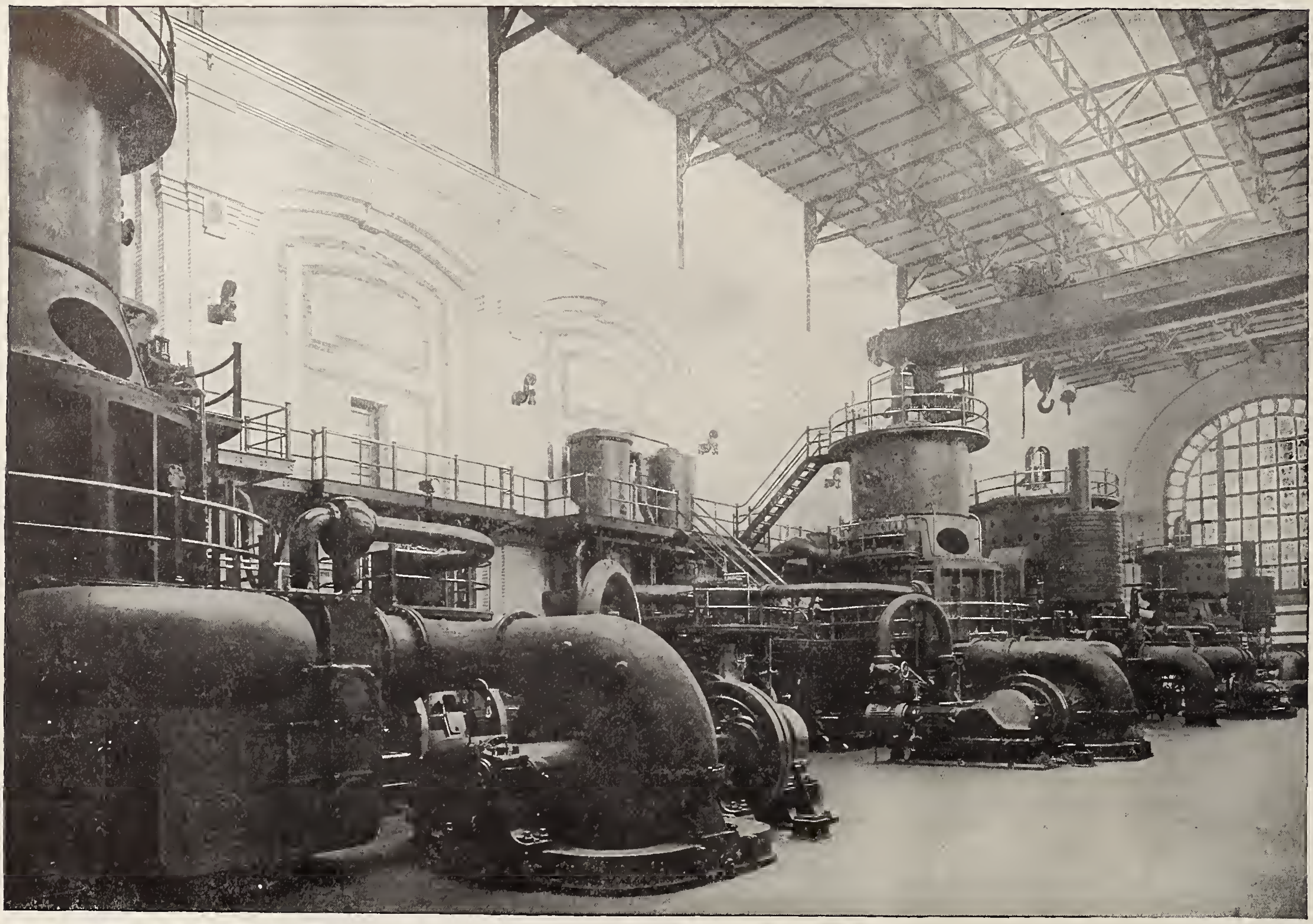


FIG. 1

5,000 KW. AND 8,000 KW. CURTIS TURBO-GENERATORS INSTALLED FOR EDISON ELECTRIC ILLUMINATING CO., BOSTON, MASS.

The following figures are given to indicate the number and size of Curtis turbines at present in operation: In the States 232 machines operate in lighting stations, each machine averaging over 2100 kw., with a total capacity of slightly greater than 500,000 kw. Railway companies are using 153 machines with an average capacity of over 1800 kw., while more than 100 machines are employed for other power purposes with an aggregate capacity of nearly 90,000 kw. These turbines only include those used for lighting and power and do not account for the small turbines of 300 kw. and under employed for excitation and other miscellaneous purposes, of which close on 700 are in use.

Outsides of the States turbines aggregating over 100,000 kw. in capacity have been installed, making a total kilowatt capacity in operation over 1,000,000 kw. at the present time. Expressed as a percentage, 55 per cent. of the total kilowatt capacity is used by lighting companies, 29 per cent. by railway companies, slightly over 11 per cent. for general power, and the remainder, practically all of which are of the horizontal type and of small individual capacity, are employed for miscellaneous purposes.

Besides those just mentioned, about 50 large vertical turbines of 1000-kw. capacity and over are now on order, aggregating a total capacity of practically 200,000 kw. The size of these machines ranges from 1000 kw. to 14,000 kw. each, the average individual capacity being nearly 4000 kw. In a list of these turbines the total capacity of units of 5000 kw. and over preponderates, showing how popular the Curtis type has become in large sizes. It is clear from the above that the vertical turbine supplies a large proportion of the total power of the country, that it is operating in a great number of big power plants and that the size of many of the units exceeds any previously built.

For economical operation very high vacuum has always been advocated, for the reason that the chief advantage held by the Curtis type lies in its power of efficiently abstracting from the steam the large amount of energy available at very low pressures. The reciprocating engine cannot operate successfully at a lower vacuum than 26 in., and hence loses a great deal of the available steam energy which the turbine utilizes down to a vacuum as low as 29 in. Condensers can be built to maintain these low pressures as readily and at no greater expense than is required for those used with other forms of prime movers. In the majority of large Curtis turbines, the condenser is located in the base, which considerably facilitates the production

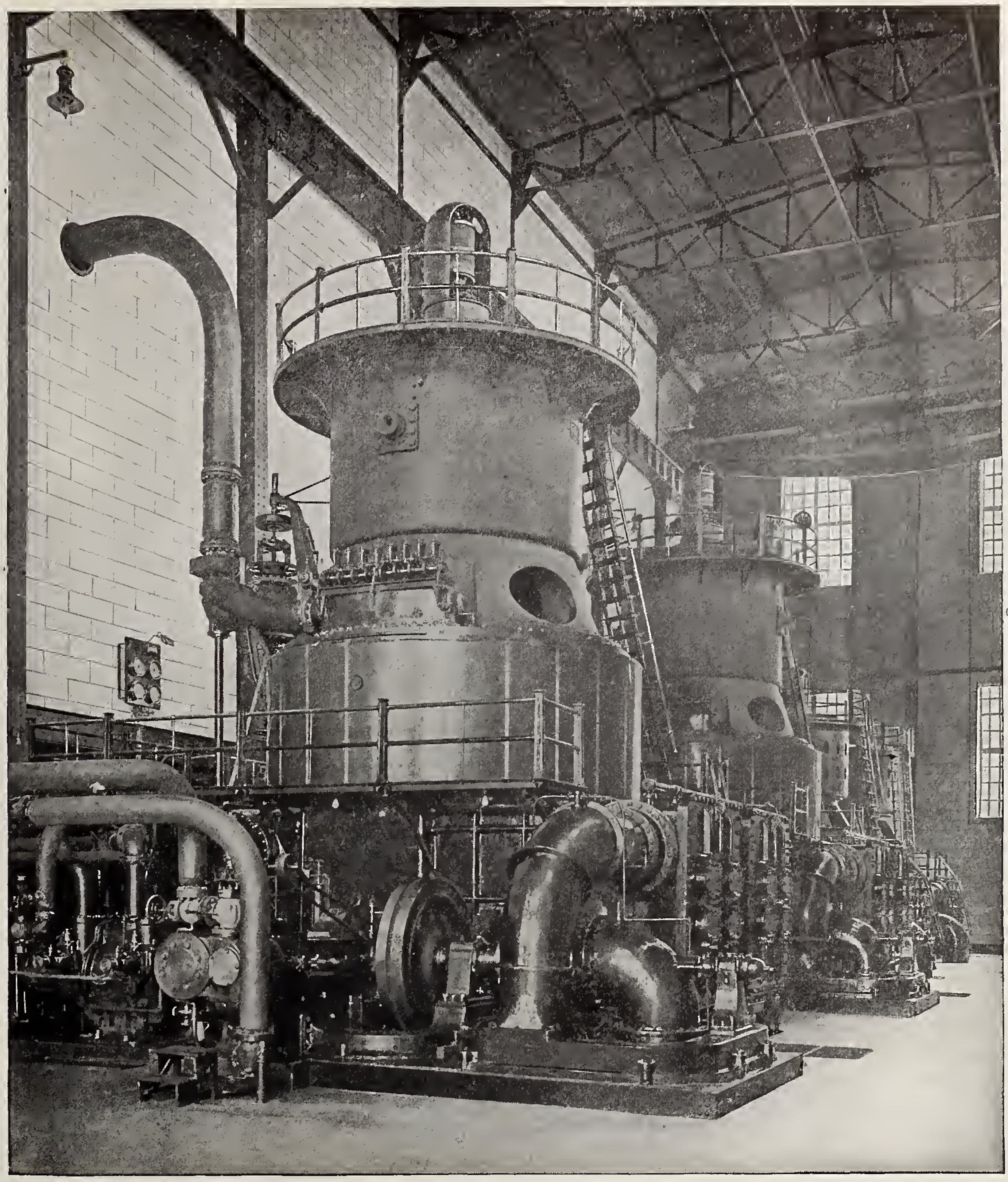


FIG. 2
5,000 KW. AND 9,000 KW. CURTIS TURBO-GENERATORS—POTOMAC ELECTRIC LIGHT & POWER CO., WASHINGTON, D. C.

of high vacuum. So economical is the operation of the Curtis type under these conditions that provision has been made in all large power stations for obtaining a vacuum of 28 in. or better; in fact, over 29 in. of vacuum is continuously maintained in many large stations where these machines are used.

In support of the foregoing statements it is of interest to note that an increase of one inch of vacuum between 28 in. and 29 in. increases the energy available from steam when operating at a boiler pressure of 200 lb. per sq. in. by 19 per cent. The Curtis turbine is able to utilize fully 80 per cent. of this large increase in energy, that is to say, the one-inch increase of vacuum reduces the coal pile as much as 15 per cent. per kilowatt-hour at the switchboard, without any additional cost being incurred.

Though the advantages gained with high vacuum are the more important, a considerable economy is gained by using a high initial steam pressure. With every 11 lb. increase of boiler pressure the coal bill is reduced 1 per cent. per kilowatt-hour, this saving being net and actually produced under operating conditions, many cases, indeed, showing even better results. Thus a wide range between the inlet and condenser pressure is the essential reason for the economy which is obtained, and it is due to the appreciation of this fact that the Curtis turbine has shown such a great advance over all other prime movers which derive their energy from steam.

The actual coal consumption obtained in the various stations using the Curtis turbine naturally varies according to the location of the plant, the type of boiler installed, the kind of coal used and many other factors. An average figure of 1.95 lb. of coal per kilowatt-hour at the switchboard is, however, a fair estimate when Eastern coal of about 13,500 B.t.u. is used, 2.8 lb. per kilowatt-hour being about the proper figure when a lower grade of coal as found in the West is employed. These figures compare very favorably with the amount of coal used with Parson's turbines or reciprocating engines of approximately equal capacity.

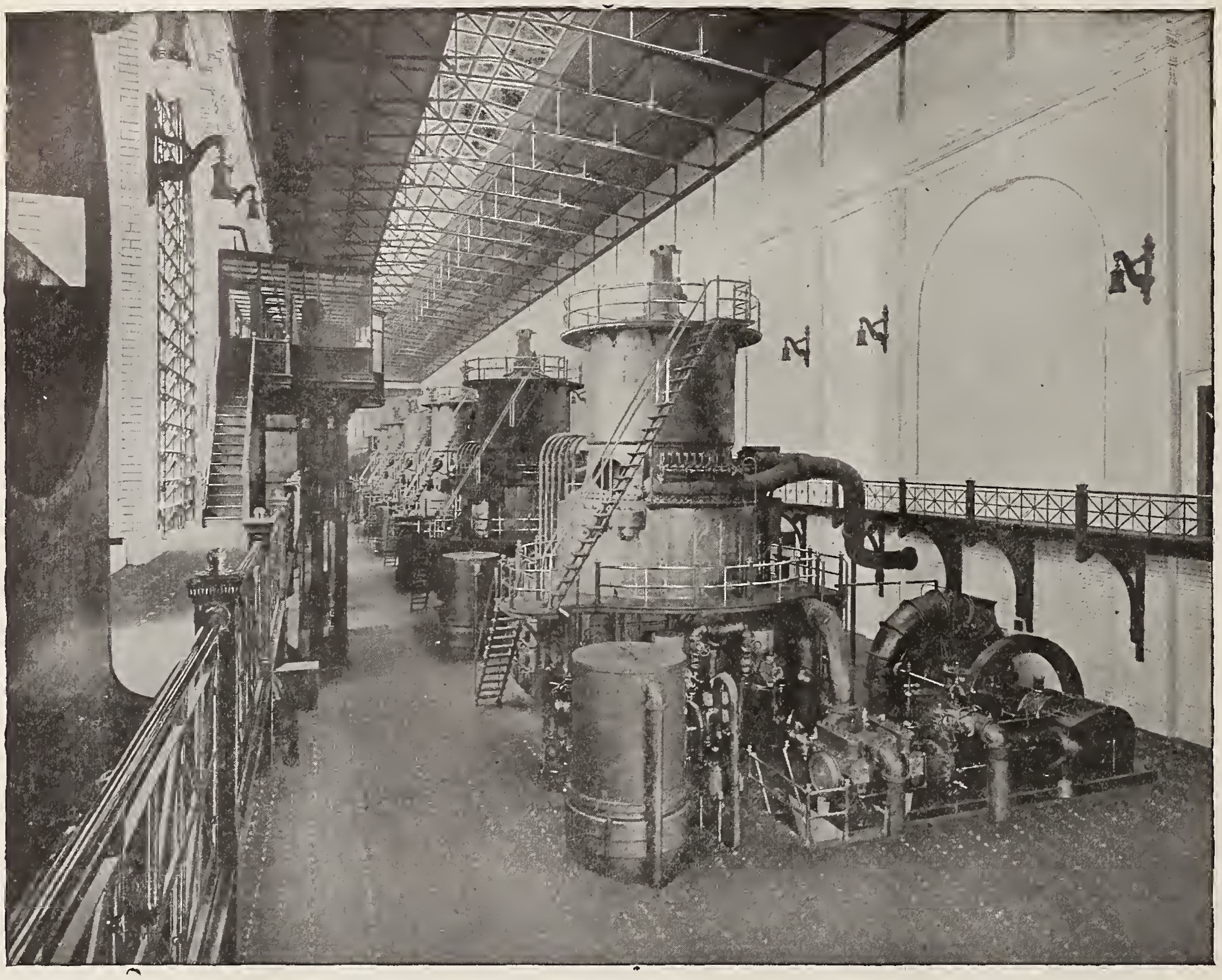


FIG. 3

FOUR 5,000 KW. AND FOUR 9,000 KW. CURTIS TURBO-GENERATORS—COMMONWEALTH EDISON CO., CHICAGO, ILL.

In respect to maintenance charges, the Curtis turbine holds an excellent record, these being in the majority of cases considerably lower than are obtained with other types of plant. The large number of turbines that have been running over a long period of time give sufficient evidence to the truth of this statement, and it is not uncommon to find many that were installed three or four years ago still operating as perfectly as when first started without having required any replacement or repair.

Besides effecting great economies in the cost of fuel and maintenance, the station staff necessary for operation is much less than is required with reciprocating engines. In a comparison between a Curtis turbine station and a representative modern engine station using the same kind of coal and of approximately equal capacity, the turbine-station labor bill per kilowatt-hour was found to be slightly less than 27 per cent. of that of the reciprocating station. The coal bill was only 81 per cent. and the total cost of operation 62 per cent. These figures were obtained by averaging over a period of more than four months and can therefore be taken as representing normal operating conditions.

If these results are figured in dollars on the basis of a 20,000-kw. power station operating at about 40 per cent. load factor, and therefore using about 70,000,000 kw-hr. per annum, the turbine station shows a saving of over $40,000 in coal, $60,000 in labor and a total saving for operation and maintenance of a little more than $110,000 per annum. Such instances are not specially selected, and others could as readily be given demonstrating equally good or even better economies.

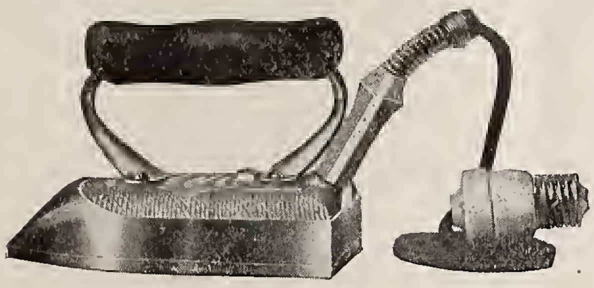
The vertical type of turbine manufactured for large powers takes up very much less space than that required by a Parson's turbine or reciprocating engine of equal capacity, and therefore quite aside from its more efficient utilization of the steam energy, which reduces the number of and space occupied by the boilers, requires smaller buildings and less land for a given output. Not including real estate, the price of which varies too much to estimate, the total first cost of a complete power station and plant will average from $50 to $60 per kilowatt for a total station capacity ranging between 25,000 kw. to 50,000 kw., $60 to $70 per kilowatt being a fair figure for station capacities between 25,000 kw. to 15,000 kw., the turbines being rated on a maximum load basis in all cases.

The use of these turbines will therefore materially reduce the amount of capitalization required for new power schemes, besides allowing a larger income to be derived from the operation of the plant, even if the price of energy to the consumer is smaller than is usually permissible when reciprocating engine or Parson's turbine stations supply the power. In addition to these advantages, the capacity of existing stations using other forms of prime movers can be often materially increased without incurring the cost of additional buildings by installing Curtis units. Many power stations have already taken advantage of this fact by installing turbines in addition to or in place of their existing plant, thereby increasing the station output with the resultant economies incident to turbine operation.

New Electrical Heating Devices

A new 6-lb. electric flat-iron, manufactured by the American Electrical Heater Company, of Detroit, is illustrated herewith. It has been sold by this company since the first of the year, and seems to have the proper qualities for a highly efficient and satisfactory laundry iron.

This new "Superior" iron is provided with a heating element of pecul-



"SUPERIOR" FLAT-IRON MADE BY THE AMERICAN ELECTRICAL HEATER CO.

iar construction. No wire is used, but heat is generated by a flat element, practically a solid mass of metal covering the entire bottom plate of the iron—in fact, being a portion of it. Thus economy of heat units and distribution is obtained, and the iron has an even heat in the point, sides, middle and heel.

The company reports a most gratifying sale of the "Superior" iron, and it has met with exceptional favor throughout this country, Canada and Mexico.

The percolator, also illustrated, is of the well-known "American Universal"

AMERICAN DISC HEATER

type. It is claimed that the percolator does not boil the coffee, but that percolation begins during the first minute after turning on the current, and in about 10 minutes the coffee is ready for serving. If a fairly good grade of coffee is used, it is claimed that ideal results are obtained.

Another new device is the new disc heater illustrated here. Its uses are well known, and every user of the heater finds it impossible to get along without it, as it may be used in a hundred and one ways around the house for such purposes as frying eggs or chops, boiling water and for innumerable other purposes, such as tea making, etc. This heater is new in design and is provided with the well-known "Steel-Clad" element, which is efficient and durable and instantly replaceable. It is finished in polished nickel, with ebonoid handles and heat-

AMERICAN UNIVERSAL COFFEE PERCOLATOR

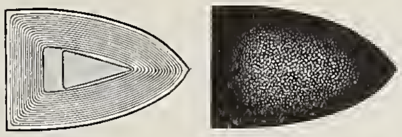
insulated legs, which prevent the device from scorching or scratching a polished surface.

Any of the devices shown here may be attached to the ordinary lamp socket, and are exceedingly cheap to operate.

An Improved Type of Electric Heater

The increasing demand for electric flat-irons has resulted in the production of many different designs, the majority of which have been steadily improved each succeeding year so that their use is rapidly increasing among the customers of electric light companies.

Realizing the actual conditions surrounding the design, manufacture, sale and application of electric irons, the Central Electric Company, Chica-



FIGS. 1 AND 2

go, Ill., made a careful investigation of the different irons and secured authentic data as to the operation under actual service conditions.

As the efficiency of an iron is that proportion of the electric energy flowing into the iron which manifests itself as useful heat on the bottom or at the ironing surface, complete tests were made by a method which measures the heat given off from the bottom of the iron only, ignoring that part given off by the other surfaces, as heat at these latter points serves no useful purpose in ironing.

The results of these tests are tabulated below as percentages of absolute efficiency. Table 1 represents the

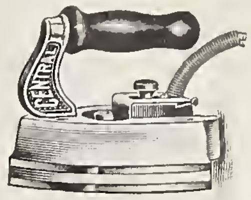


FIG. 3

new Central "Universal" iron, Table 2 represents a second type of iron on the market, and Table 3 represents the averages of seven other irons which have been on the market for the past two or three years.

To effectually and quickly iron damp or wet goods it is essential that the nose, or point of the iron be hot-

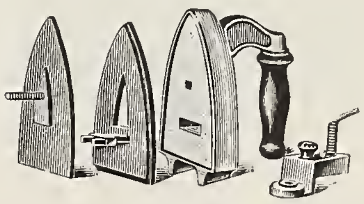


FIG. 4

ter than the center. If this feature were not taken care of by proper design the point would cool to such an extent that the speed of ironing would be materially reduced.

In the "Universal" iron the desired heat distribution is secured by so locating the heating element that the edges and points of the ironing plates are initially hotter than the center. The location and construction of this improved heating element is clearly shown in Fig. 1 and the heating effect is illustrated by the well-known burned paper diagram, Fig. 2.

It is interesting to note that an iron "snaps" at approximately 250° F. The ordinary domestic iron is better at 400° F. and the average laundry iron at approximately 500° F.

Again referring to the tabulated data given above it will be noted that on the basis of 250° F. at the bottom of the iron, the temperature at the top

	Table No. 1	Table No. 2	Table No. 3
Absolute efficiency	60%	50%	39%
Current Consumption	400 w.	475 w.	533 w.
Time required to heat bottom plates to 250 degrees F	2 min.	$3\frac{1}{2}$ min.	$4\frac{1}{2}$ min.
Temperature of top at same time	72 degrees F.	100 degrees F.	137 degrees F.
Time required to heat bottom plate to 500 degrees F.	5 min.	8 min.	13 min.
Temperature at top at same time	150 degrees F.	250 degrees F.	398 degrees F.

of the various types varies from 72° to 137° F., and with a temperature of 500° at the bottom of the iron, the temperature at the top of the various irons varies from 350° to 398°.

It is claimed that the iron shown in

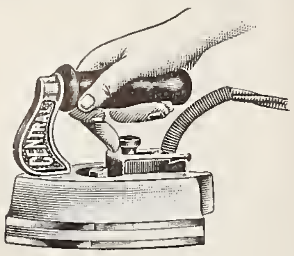


FIG. 5

Table I is much superior to those covered by the other tables in that the top of the iron runs much cooler and less heat is radiated and wasted from this point.

Fig. 3 illustrates the improved iron, the tests of which are shown in Table I. Fig. 4 illustrates the various elements. It will be noted that the heating element is firmly clamped between the body of the iron and the ironing plate, which is shown in the reverse position, illustrating the method by which it is bolted to the upper element. Fig. 5 illustrates the method of operating the heat-regulating switch, by the use of which the operator can keep the iron at a definite temperature with a minimum consumption of energy. As a matter of interest it might be stated that the 6½-lb. "Universal" iron consumes approximately 400 watts.

A Model Aluminum Lightning-Arrester Installation

The Schenectady Power Company's system is protected by an interesting and thoroughly modern installation of aluminum lightning arresters. From a 40-cycle three-phase generating station on the Hoosic River, near Schaghticoke, N. Y., about 1200 kw. at 32,000 volts is transmitted 21 miles to the works of the General Electric Company at Schenectady, N. Y.

The transmission lines are in duplicate and are supported on specially constructed steel towers, the link type of suspension insulator being used. Although the line crosses both the Hudson and Mohawk Valleys at points where lightning is very severe, no special protective apparatus was designed to meet these conditions. Arresters of standard design are in use, and they have given entire satisfaction since they were installed. A ⅜-in stranded steel wire, grounded at each tower, is supported above the lines at the tops of the towers.

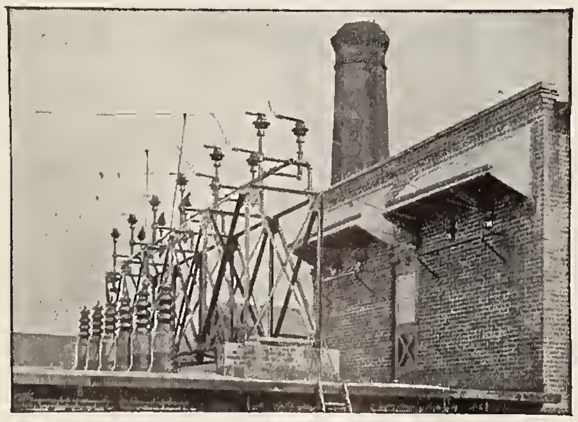


FIG. 1
INCOMING LINES AT SCHENECTADY TERMINAL OF SCHENECTADY POWER CO.'S SYSTEM

The generating station and the substation at the Schenectady end are both equipped with aluminum arresters of the latest design. The construction

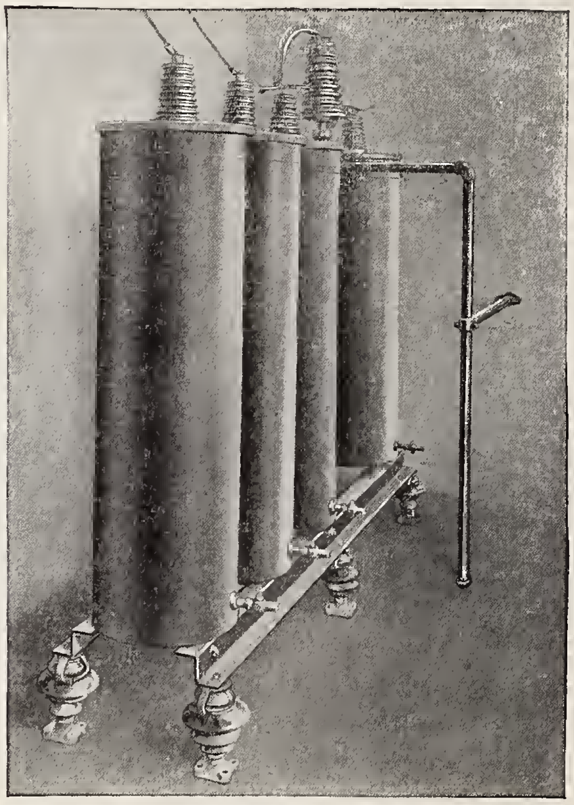


FIG. 2
INTERIOR OF ARRESTER COMPARTMENT SHOWING ALUMINUM LIGHTNING ARRESTERS

of these arresters is very simple. A series of aluminum cones, each being partially filled with an electrolyte, is rigidly held together, the complete unit being immersed in oil in a steel tank and connected to ground and line. An adjustable horn-gap is placed between the arrester and the line.

The useful characteristic of the type of aluminum arrester used in this installation is its critical voltage, which depends upon the formation of a thin film on the surfaces of the aluminum cones. This film normally has a very high resistance, and up to its critical voltage point allows exceedingly low currents to pass, but above this point the current is limited only by the internal resistance of the electrolyte. The closest analogy to this action is found in the well-known safety valve of the steam boiler. On the aluminum plate are myriads of these safety valves, so that if the electric pressure arises above the critical voltage, a free discharge takes place equally over the entire surface.

When the arrester is not in operation the film dissolves slightly in the electrolyte. In order to keep the film in good condition provision is made so that the arrester can be momentarily connected to the line each day.

Besides serving as spark-gaps to prevent full voltage from being continually impressed on the arresters, the horn-gaps serve as short-circuiting switches to momentarily connect the arrester to the line and also as disconnecting switches to isolate the arrester from the line when desired.

The arresters on the Schaghticoke system are designed to discharge continuously for half an hour, although in actual tests arresters of this type have discharged continuously for two hours. Half an hour, however, is considered sufficiently long to remedy whatever trouble may be on the line. When a phase becomes grounded and the arrester begins to discharge, an alarm bell attracts the attention of the operator. This discharge alarm consists of a single aluminum cell placed in the ground connection to the arrester proper and an ordinary electric bell in shunt with the cell, the bell ringing only when current passes to ground.

The accompanying illustration, Fig. 1, shows the incoming lines at the Schenectady terminal and the substantial manner in which the construction is carried out. The main lines enter the station through six roof-entrance bushings, the arresters being installed in the raised portion of the station shown at the right of the illustration.

In Fig. 2 is shown the interior of the arrester compartment. As this is a non-grounded neutral system, four stacks of cones are used, a multiplex connection giving equal protection between the lines, as well as between line and ground. The transfer switch, shown between the third and fourth tanks in the illustration, is used to interchange the connections between these stacks of cones, so that the cells may be equally charged when they are daily connected to the line.

The installation is very compact, the distance from the floor to the top of insulators being about 85 in.; the length of the supporting frame is about 93 in.

At the Schaghticoke end of the line the arresters are installed in fire-proof compartments in the rear of the switchboard, while the horn-gaps are located on the roof of the power-house.

Similar installations of these arresters have been made on other high-tension transmission lines in different

parts of the country, notably on the system of the Southern Power Company and the high-tension lines of the Animas Power & Water Co. in Southern Colorado. The operating record in the latter installation is an extremely interesting one, the number of shutdowns due to lightning being reduced 88 per cent. in a single year. In this, as in other installations, the arresters have required no attention whatever, except the regular charging required to keep the film in good condition.

A New Portable Ventilating Set

For the ventilation of small rooms or a portion of a building not well ventilated by natural means or by a complete fan system, small fans have been used. These have usually been of the so-called desk or propeller type because of cheapness and portability. It is a common sight in any large office to see nearly all of the desks equipped with small fans setting in motion the air in the room. The fans, however, produce ventilation that may be termed "apparent," but with a little consideration one can see that the ventilation is not real, for the foul and overheated air is not removed.

STURTEVANT PORTABLE TESTING SET USED IN EXHAUSTING VITIATED AIR FROM A ROOM

The B. F. Sturtevant Company, of Hyde Park, Mass., is now placing upon the market a new electric ventilating set, which has the great advantage of producing real ventilation. It does not stir up overheated and vitiated air and send it whirling around the room, but removes it completely so that fresh, pure air may take its place. It is true that this fan is a little more expensive than the desk type, but the results obtained are well worth the difference.

It is built in three sizes, all of which are so small as to be readily carried about the building, yet they positively deliver a volume of air so large and at such pressure, as to make them decidedly useful. The smaller size weighs but 25 lb. and delivers 150 cu. ft. of air per minute at an operating expense of about one cent per hour. The largest size weighs only 50 lb., but delivers 400 cu. ft. of air at a cost of less than three cents per hour. The smaller sizes of these sets are especially adapted to residences, clubhouses, etc. Easily transferred, they may be used for ventilating a sitting-room or parlor, removing cooking odors from the kitchen, or ventilating the cellar.

In many residences the draft for the furnace is so weak that much time is required before an appreciable quantity of heat is available. With one of these small blowers the draft can be quickly accelerated so that the heat will be available immediately.

STURTEVANT PORTABLE VENTILATING SET USED FOR PRODUCING FORCED DRAFT

These sets, to which have been given the name "Ready-to-Run," consist of a small dust-proof motor driving a cased fan of the multivane type. This type of fan is the latest development in the centrifugal type, and because of its great capacity in a small place, delivers a large volume of air, larger, it is claimed, than any other fan of the same size and weight. To meet all

conditions they are equipped with alternating or direct-current motors and are supplied with a flexible canvas hose for the outlet and a cord and plug so that the set will be "Ready-to-Run" at a moment's notice. Installation work is unnecessary with one of these sets, for it is made ready for operation by simply putting the plug in the electric-light socket and turning the switch.

Motor-Driven Concrete Mixer in Record Performance

One of the most noteworthy buildings of re-inforced-concrete construction in the west is that being built for the Sacramento Hotel Company, Sacramento, Cal. Messrs. Sellon and Hemmings, architects for the State of California, designed the building, which covers a lot 160 ft. by 140 ft. on a site a block distant from the Capitol, and consists of basement, first and mezzanine floors, and three floors for guests rooms.

In planning for the construction of this large building, the general contractor, the Ransome Concrete Company, of San Francisco, took pains to install an equipment which would be thoroughly reliable and durable, and also insure the rapid handling of materials.

The principal element of the plant, the concrete mixer and hoisting-machine, was especially designed for the Ransome Concrete Company by C. G. Meyers, of Norman B. Livermore & Company, San Francisco, Cal, to meet the requirements of heavy continuous service. The concrete machine consists of a special combination Ransome concrete mixer mounted on a 10-in. steel I-beam frame. On the end opposite the mixer is mounted a Mead-Morrison single-drum hoist. Both mixer and hoist are arranged to be driven directly through gearing by a 30-h.p. Westinghouse alternating-current motor operating at 850 rev. per. min. on 200-volt, 60-cycle, three-phase current and equipped with the necessary auto-starter. The mixer is provided with a patent water-measuring device and a measuring hopper. The hoist is used in operating the concrete hoist-bucket. The whole arrangement forms a compact machine, the steel frame giving great stability to the outfit.

The mixer was set up in its permanent location in the basement under the sidewalk and retained in that location until all the concrete had been deposited in the building. Crushed rock and gravel was brought to the site by teams and dumped into large material bins, from which it was fed by means of a belt-conveyer to a large charging hopper mounted above the mixer. After mixing, the green concrete was hauled by means of concrete carts to the moulds.

That the arrangement as installed was an efficient one is well demonstrated by a record made September 3, 1908, when the company placed 381 cu. yd. of concrete in 8¾ hours. This involved the mixing of 315 cu. yd. of rock, 158 cu. yd. of sand and 572 bbls. of cement; a total of 551 cu. yd. of loose, dry material, which weighed in the aggregate 1,427,000 lb. The addition to this dry material of 460 bbls. of water brings the actual weight of material handled to 1,547,600 lb. All the material was raised on a hoist-bucket a height of 15 ft. and dumped into a bin fitted with two concrete bin gates. From here it was distributed to the forms, using 10 concrete carts as carriers.

The maximum haul for placing this concrete was 225 ft., the average haul 150 ft. By average haul is meant the distance which the material had to be carted, the round trip being twice that distance. In doing this work but 10 men were used in wheeling the 10 carts, each man handling his cart alone and working the full day, so that the average amount of material placed by each during the day weighed over 75 tons. The material was thoroughly mixed in the mixer and, in addition, was turned over four times in being handled between the mixer and the forms.

Movement against Gasoline in Colorado

The Colorado Electric Light, Power & Railway Association has been for some time actively engaged in combatting the gasoline evil in the State of Colorado. Two years ago, through the efforts of the association, a bill was passed by the State Legislature covering an amendment to the law then on the statutes, which prevented the use of gasoline except only when tanks were placed under ground, exterior to the buildings in which gasoline lighting was used. The manufacturers of the gasoline apparatus fought the law as applied to a consumer in Denver, who was brought up before the court and fined, the lower court upholding the law.

Following is a copy of the amendment. The matter is still in the courts, preparatory to being carried to the supreme court of the State of Colorado.

PETROLEUM OIL
(Inspection of).
AN ACT

To amend an Act entitled an Act providing for the inspection of all kinds of petroleum oil that shall be used for illuminating purposes, regulating the sale of said oil, providing for certain appointments and removals to be made by the Governor, defining what shall constitute certain misdemeanors, prescribing penalties, and containing other matters properly connected therewith. Approved April 14, 1899.

Be it enacted by the General Assembly of the State of Colorado:

Section 1.—That the act entitled an Act providing for the inspection of all kinds of petroleum oil that shall be used for illuminating purposes, regulating the sale of said oil, providing for certain appointments and removals to be made by the Governor, defining what shall constitute certain misdemeanors, prescribing penalties, and certain other matters properly connected therewith, approved April 14, 1899; be, and the same is hereby, amended by adding the following section thereto:

Section 14.—Any person who shall knowingly sell or use for lighting or illuminating purposes any oil of any kind before the same has been duly inspected and approved as required by this Act shall be fined in the sum not less than twenty dollars ($20.00) nor more than two hundred dollars ($200.00), provided that the provisions of this Act shall not apply to sperm, lard or gasoline used for illuminating purposes in lamps for lighting streets, public ways, alleys or mines. Also the gas or vapor from such oils may be used for illuminating purposes where the oils from which said gas or vapor is generated are contained in reservoirs under ground outside the buildings illuminated or lighted by the gas generated from the gasoline. All gasoline oils sold in the State of Colorado for heating, burning or power purposes shall be tested in the following manner: By hydrometer for specific gravity. The temperature at the line of test shall be from 15° to 18° C. or 60° F.; the specific gravity to be marked on the tanks, casks, packages or barrels, the same as provided in this Act for other oils, and the same fee shall be paid as provided herein.

Approved April 8, 1907.

What might be called a pocket edition general catalog has just been issued by the Joseph Dixon Crucible Company, of Jersey City, N. J. This lists their principal products, such as crucibles, facings, lubricating graphite, greases, pencils, protective paint, etc., giving brief descriptions and prices. The booklet is of commercial envelope size, and will conveniently go in the pocket or desk pigeonhole. It is substantially bound in tough cover stock and attractively printed.

An Insulating Transformer for Telephone Lines

An insulating transformer for use on telephone lines, recently placed on the market by the General Electric Company, is shown in the annexed illustration. The purpose of this transformer is two-fold:

First, to safeguard the users of telephones from the dangers of high voltage, due either to induction or accidental contact between telephone and power lines, where these lines are on the same pole or upon a parallel adjacent line of poles.

Second, to improve the telephone service by removal of the ordinary small ground gap carbon arrester from direct connection with the line, as well as to obtain better insulation by removing the interior wiring, instrument, batteries and other parts from direct connection with the line.

Special attention has been given to the electrical and mechanical design of the transformer; the high-frequency talking currents are transformed with small loss, while at the same time the magnetizing current, which must be supplied by the ringing generator, is vey small. Tests show that the magnetizing current taken by this transformer is about half the

FIG. 1—INSULATING TRANSFORMER FOR TELEPHONE LINE

current passed by a standard 1000-ohm bell. As can be seen from Fig. 1, the insulating transformer is assembled in a weatherproof iron case, and may, if desired, be installed out of doors and mounted in any convenient place.

In designing this transformer the insulation has been considered of primary importance. A high-potential test of 25,000 volts between windings for one minute is given to each transformer before shipment. The high

FIG. 2—SWITCH, FUSE AND LIGHTNING ARRESTER UNIT

insulating quality assured by this test makes the transformer a sturdy piece of apparatus under ordinary conditions of operation, but the best protection is afforded when it is installed with a combined switch, fuse and

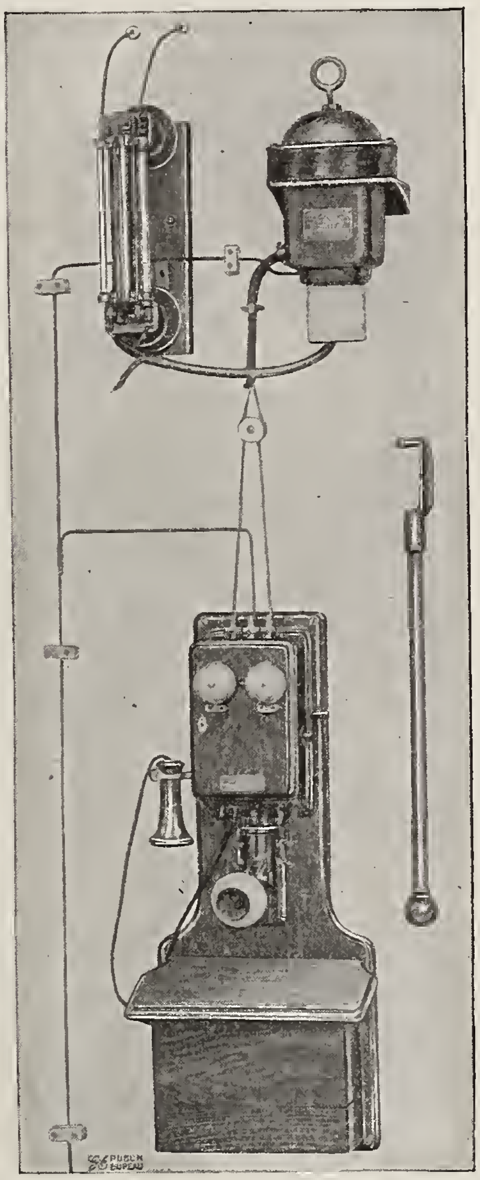


FIG. 3—SHOWING ARRANGEMENT OF TELEPHONE TRANSFORMER

lightning arrester. This combination affords the greatest safety to both the even in the most extreme cases when the telephone lines come in actual contact with a high-tension power circuit. telephone instruments and the user,

The switch, fuse and lightning arrester combination recommended for this service is shown at the top of Fig. 2, the whole being mounted on a base of insulating material. The long-handled insulated hook at the right of the illustration is used to pull the switch open when it is desired to disconnect the telephone and transformer from the line. The arrester is hinged at the bottom, the insulated hook engaging with a ring at the top of the arrester. The usual form of carbon arrester with mica separation is used to protect the winding of the transformer against any abnormal difference of potential which might accidentally exist between the telephone lines. This arrester is connected across the terminals of the transformer, but is not connected with the ground.

An adjustable gap arrester is connected between the telephone lines and ground, the function of this arrester being to take care of lightning discharges and, in case of actual contact with high-tension lines, to arc over and blow the fuse, thus disconnecting the transformer and telephones from the line. Should a ground occur on the adjacent high-tension line, the voltage induced on the telephone line will not materially interfere with the service, provided the line is sufficiently well insulated. The adjustable air gap is set just beyond the point where this induced voltage will arc across.

Tests on a 30,000-volt transmission line in actual operation showed that a ground on one phase of the transmission system induced a potential on the telephone line of approximately 7000 volts, measured between telephone line and earth. Notwithstanding this high-induced voltage on the telephone line, it was possible to use the telephone when the transformer was installed. The line was somewhat noisier than under normal conditions, but not so noisy as to prevent comprehensive conversation.

The Executive Committee of the Museum of Safety and Sanitation, of 29 West Thirty-ninth Street, N. Y., has detailed Dr. Wm. H. Tolman, the Director, for field-work, and he will start May 1 on a lecturing tour. Chambers of commerce, manufacturers' associations, engineering, insurance and architectural societies, railway and other clubs may avail themselves of this illustrated exposition of devices and methods for reducing damage suits and preserving efficiency for the cost of the lantern operator ($10), if not too far removed from the itinerary.

A New Flat-Iron

A new flat-iron recently brought out by the General Electric Company embodies new features in material, construction and shape.

The resistance metal used is named "Calorite," and is capable of withstanding oxidation to a point several hundred degrees hotter than any metal previously used in heating devices, its melting point being 2370° F. The resistance of "Calorite" is twice that of nickel-silver and 73 times that of copper, and it is this high specific resistance which enables it to be used in a single thin grid-layer, or leaf. In the majority of designs the heat must either pass through two or more layers of heat insulation or radiate through an insulating air space. The "Calorite" leaf unit has such close thermal relation to the working surface of the iron that it cannot overheat. This construction obviously precludes the use of any auxiliary protective device to insure the life of the heating unit.

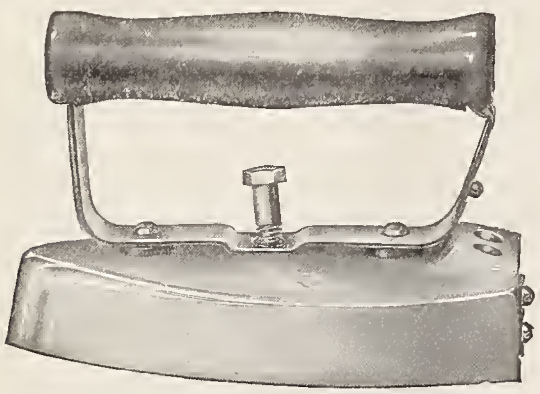


FIG. 1—NEW GENERAL ELECTRIC FLAT-IRON

In the new iron the heat is evenly distributed over the entire working surface. A scorch proof shows that this is practically as well as theoretically true. The toe, the heel and both sides are heated equally, providing for efficient ironing in any direction.

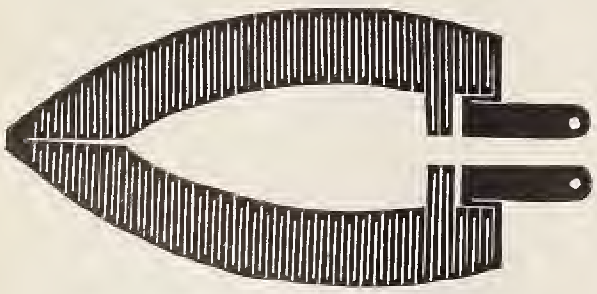


FIG. 2—SCORCH PROOF OF NEW IRON

The construction of the iron is very simple and rugged. The body is of two hard gray cast-iron plates held together by two heavy steel bolts. The thin-leaf unit is firmly clamped between these plates and separated from them only by a sheet of clear amber mica two thousandths of an inch thick, which provides the necessary insulation.

The shell cover, held by one bolt, carries a well-made handle riveted to it, a continuous air jacket being formed between this shell cover and the working part of the iron. This insulating air jacket not only covers the top of the iron, but the sides and ends as well, and the use of the objectional asbestos is eliminated.

The attachments are of the most approved design and are made of unbreakable material, the use of porcelain being entirely avoided. The leaf-unit flat-iron will be equipped with a plain attaching plug, with combination indicating switch plug or with permanently attached cord, if desired.

The few parts of the flat-iron are readily interchangeable, and the iron can be completely taken apart by removing three bolts. The new leaf-unit iron is available in the five-pound, or 450-watt size, and the six-pound, or 550-watt size. The iron is finished in highly polished nickel.

Lighting Company Reorganized

The reorganization of the United States Light and Heating Company, which owns the Bliss system of electric car lighting, the National Battery Company of Buffalo and the United States Light and Heating Company of New Jersey has recently been completed.

The new board of directors consists of Edwin Hawley, W. H. Silverthorn, President Railway Steel Spring Company; Jules E. French, Chairman Board of Directors of the same company; C. A. Starbuck, President New York Air Brake Company; W. S. Crandell, with Mawley & Davis, bankers; Theodore P. Shonts, President Interborough-Metropolitan Company, and Newman Erb, President Wisconsin Central Railroad Company.

The officers are: W. H. Silverthorn, President; Jules E. French, First Vice-President; Edwin Hawley, Second Vice-President; C. A. Starbuck, Third Vice-President, and W. S. Crandell, Secretary and Treasurer.

News Notes

The Rockford Edison Company, of Rockford, Ill., gave a dinner, March 13th, to the electrical contractors, architects and members of the press. The event was enlivened by the presence of J. Robert Crouse, who outlined the National Co-operative movement to promote the more extensive use of electrical service. F. H. Golding is manager of the Rockford Edison Company.

The Northern Engineering Works, of Detroit, Mich., are building two three-motor, 66-ft. span electric traveling cranes for export to Japan. These cranes, which are for a prominent steel works, will be equipped with the new type "E" trolley.

Lester G. French, formerly editor of *Machinery*, has been engaged to direct the editorial department of the American Society of Mechanical Engineers.

"Permanite" packing, manufactured by the H. W. Johns-Manville Co., of New York, is described in a pamphlet recently issued. It is claimed that this packing, which has an asbestos foundation, has the same resiliency and pliability as rubber-sheet packings and yet may be used for superheated and high-pressure steam.

James Jones, of the Jones Fan & Motor Co., of New York, died recently of pneumonia. He was for 25 years the factory partner of Pierce & Jones, manufacturers of electrical instruments, and later with his son formed the firm of J. Jones & Son, manufacturers of general electrical supplies.

A new bulletin recently issued by the Bristol Company, of Waterbury, Conn., describes a number of recording instruments especially adapted for blast furnaces, including recording pressure gauges, recording thermometers, electric time recorders and indicating and recording electric pyrometers. The text explains fully how these may be applied.

Among the orders just booked by the Allis-Chalmers Co. are those for three gas engines, aggregating 1000 h.p., direct connected to three Allis-Chalmers electric generators, for the Palmetto Phosphate Co., of Tiger Bay, Fla.; a gas engine of approximately the same size, with generator, for the Armstrong Cork Co.'s plant at Camden, N. J.; a 1500-kw. gas-driven electric unit and seven standard 30,000 cu.ft. gas-driven blowing engines for various blast-furnace plants. During the past 90 days the company has taken contracts for more than 30 steam turbines and generators, aggregating in capacity nearly 50,000 kw., and negotiations are now pending for more than double that number. Among the orders recently placed is one for a unit of 200-kw. for the Public Service Corporation of New Jersey, to be installed at Camden; another of 2000-kw. purchased by the Stone & Webster Engineering Corporation for the El Paso Electric Ry. Co., El Paso, Tex., and a 2000-kw. machine to be placed on a "repeat" order in the Public Service station of the City of Columbus, Ohio.

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CONTENTS

Current Limiting Reactance Coils

The paper by P. Junkersfeld at the recent convention of the N. E. L. A. on "The Use of Reactance Coils in Generating Stations," following closely on the experiences of the New Haven system as described in B. G. Lamme's discussion to Murray's paper before the A. I. E. E. last December, in which the enormous short-circuit currents of the turbo-generators in the power house at Cos Cob caused destruction of oil circuit-breakers and damage to armature windings, bring prominently to the front the question of the availability as a protective means of reactance coils in the leads of such generators.

Such coils are intended specifically for current limiting purposes and are entirely distinct from the lightning arrester choke coils frequently used in the same location.

The specific difficulty which the limiting coils are intended to eliminate is the mechanical bending of the armature conductors with the consequent insulation breakdowns, short circuits and general damage. The effectiveness of oil circuit-breakers is very severely strained at the same time.

Broadly speaking the action is as follows: A generator in operation consists of a magnetized field pole across the face of which is driven a series of armature coils, partially embedded in the iron of the core and partly unsupported at the ends. E.m.f. is generated in these coils and current flows therein. As a result of this current the armature coils feel a mechanical or magnetic torque, due to the field magnetism which is exercised largely within the iron as this is where the major portion of the magnetism is. This torque is directly proportional to the current and to the magnetic strength. But there is some stray field outside the iron so that there will be some strain produced on these end portions of the coils. Although this latter strain is much less than the strain in the slots, yet the fact that the coils are nearly unsupported relatively, outside the iron makes the resultant condition there more dangerous.

Again current flowing in any coil causes magnetic or mechanical strains independent of the proximity of any field coil. The well-known law governing this case is that any coil will tend to move, that is, to deform itself, so as to enclose the greatest number of lines of force. Therefore a square corner will try to become round and all parallel turns carrying current in the same direction will crowd together. In this case the strain is proportional to the square of the current, for the current in any one wire of the coil lies in the field produced by the other turns nearby and so has a tendency to move in virtue of its presence in this field. Since any increase of the current in the coil will increase both the field in which the wire lies and the current in the wire itself, the magnetic force will be increased as the square.

Still another strain will be produced by currents in the armature coils where two coils lie adjacent or overlap as they do in an armature on the ends. Thus it is clear that excessive current in the armature will cause magnetic and mechanical strains in many directions and that their exact or their maximum amount or location will be difficult to determine and will vary from one case to another.

Returning to the revolving armature again, it is clear that the current therein is determined by the voltage generated and the total impedence of the circuit, including the impedance of the armature winding itself.

In the so-called slow or standard speed types of generators which are connected to reciprocating engines or water wheels, the impedance of the armature itself is sufficient to require a voltage of somewhere near one-tenth of normal voltage to put normal current through it. This value of course varies much, but for the purposes of illustration ten per cent. may be used.

If now a short circuit occurs at the terminals of the generator, and if the voltage generated remains the same for the instant, the impedance in circuit being only the armature impedance, the current will increase to ten times full-load circuit. This increase in armature current will cause an increase in the mechanical strains just described greater than normal either in direct proportion or as the square, according as to which strains are under consideration, all as pointed out above. This will easily cause dangerous mechanical strains in unfavorable designs, especially in high voltage machines where the armature conductors are small and mechanically weak.

But the e.m.f. generated in the armature under the short circuit condition will not remain at the original value but will be reduced by the well-known demagnetising action of the lagging current in the armature. At the instant of the short circuit the armature current, on reaching full value, opposes the normal field coils and the field magnetism starts to collapse, but the decrease of its magnetism sets up eddy currents wher-

ever possible in the core of the field, which eddy currents tend to neutralise the demagnetizing effect of the armature current, for the moment at least. But the eddy currents are maintained only by the falling of the field magnetism and so the field will soon reach its equilibrium, which is much less than the normal full load value. The net result is that the eddy currents delay the falling of the field magnetism, perhaps only a few cycles. But during this brief period most of the damage that can be done by the mechanical forces set up by the excessive short-circuit current is accomplished and the field reaction is thus too slow to protect the winding from this particular danger. It will, of course, protect it against any heating effects, except such as will properly be caused by the normal permanent short-circuit current.

In the type of machine just assumed, in the final state it may be expected that the field magnetism strength and consequently the e.m.f. generated will drop to about 30% of the normal value and that this 30% will be absorbed by the impedance of the armature itself so that about three times full-load current will flow.

The effect of dampers on the poles of the field magnets, such as are used to prevent hunting, will be to increase the eddy currents greatly, and so increase the time taken for the field magnetism to die down from full-load voltage to the 30%, or short-circuit value, thus giving the excessive mechanical strains time to accomplish all the harm of which they are capable.

Up to the advent of the steam turbo-generator such was the condition of affairs. In a number of instances, great damage had been done to generator windings by excessive short circuit but by greatly strengthening the windings themselves mechanically, it was concluded that the danger of serious damage was removed. However, in cases where there were several large generators operating in parallel, the severity of the mechanical strains manifested in one of the machines which might develop a short circuit seemed nearly irresistible by any feasible construction. This was one reason for the use of a resistance in the grounded neutral.

With the introduction of large turbo-generators the condition is almost uncontrollable on account of the great natural increase in the magnitude of the short-circuit currents of these machines in the largest capacities. If the speed of a given generator is doubled the voltage and consequently the capacity with the same armature current is doubled. The armature impedance however remains the same, so that the short-circuit current is doubled with all the consequent increase in mechanical strains. This illustrates why the very high speed turbo-generators are in a special class in considering this matter. Of course the design of the high-speed machine is modified in many particulars from the moderate speed machine and the increase in speed is not the only change made but the net result is that the turbo-generator has a very much higher short-circuit current than the slower speed machine. In some other ways as well it is at a disadvantage for the greater distance between poles tends to keep down the armature impedance and also to make it more difficult mechanically to support the longer end connections.

Another factor of importance in determining the severity of short circuits is the frequency of the generator. A 60-cycle machine is much less likely to trouble, on account of its greater armature impedance, than a 25-cycle machine.

Single-phase machines are in some ways more difficult to protect than those of three-phase.

It is this situation, minimized as far as possible by the manufacturing companies, that has brought forward the use of current limiting reactances. This remedy was adopted at the Cos Cob power house of the New Haven, as has been very carefully explained by Lamme in his admirable discussion to Murray's paper above referred to. This is probably the most severe case that has ever arisen and is not likely to be seen again in view of the knowledge there acquired. But this is a serious matter in other places and if the limiting inductance is a satisfactory remedy it is very likely to be frequently used.

Its action is clear enough, for the permanent including of the additional inductance in the leads of the generator has the effect of the greater armature impedance of the older type machines and limits the short-circuit current, not especially the ultimate permanent short-circuit current, but the instantaneous excessive short-circuit current which is the cause of most of the mechanical trouble.

But the limiting coil has many disadvantages.

I. It permanently affects the regulation of the generator, for it is always in circuit and must absorb voltage. Junkersfeld gives the estimated value of 2% as the increased drop due to the limiting coil, presumably figured for a particular case. This is not as important as it might seem, for such large machines as would require coils would have automatic regulators or would be called on only for such slow changes of voltage that the field could easily be changed by hand to meet the conditions. The fact, however, that the *output* of the generator would be reduced nearly in this proportion (2%), is a much more serious matter.

II. It reduces the efficiency of the combination, estimated by Junkersfeld at one-half to one per cent.

III. The size and cost of the coils is astonishing, until it is remembered the full-load output of the whole generator for a short time. Junkersfeld again estimates for a 10,000 kw. generator three coils each occupying a cubic space five foot on a side.

Iron cannot be used to great advantage in these coils for its permeability will so increase on the normal load condition over the much more nearly saturated short-circuit condition that the drop at normal currents would be greatly increased. This again increases the size and cost of these coils.

Again as Junkersfeld properly says, the limiting coils must be built very ruggedly indeed, for on account of the great concentration of turns the magnetic forces will be tremendous.

IV. If these coils are to be relied upon to serve also as protection against static disturbances, to which they will normally be exposed in any case, they must be highly insulated, still further increasing their expense. It is of course true that with every short circuit there is a static surge, preceding the normal excessive current rush, due to the electrostatic capacity of the windings, but while this is a threat of puncture to the insulation of the end turns, it is not serious in its mechanical effects.

V. If the short circuit occurs within the winding of the armature no external coil will limit the flow of current, and even if placed in the neutral connection it would be of no great avail against local mechanical injury.

All things considered it would seem that these coils should be avoided wherever posible; and as far as feasible the internal design of the generators should be such as to limit the natural short-circuit current of the machine, especially if in so doing any gain of efficiency or cost can be obtained. This whole matter, however, is now in a formative stage and no one can yet foresee the final outcome. Special cases are being worked out but until these coils have had a more extended use and until new machines have been designed in the light of present knowledge and are tried out, it will be impossible to say how extensively, if at all, these limiting reactance coils will be used.

A Boiler Wreck

On Tuesday evening, 6:15 P. M., at Denver, Colo., a vertical 400-h.p. Wickes steam boiler exploded in the main power station of the Denver Gas & Electric Co., at Sixth and Lawrence Streets. Three men were killed outright and five were badly injured.

The entire boiler shell, weighing about 35 tons was thrown almost vertically through the roof to a length estimated by various observers at from 300 to 500 ft. and then fell back upon the station, crashing through two floors of the building and falling on a 600-kw. belted alternator, destroying it and a similar 500-kw. machine alongside, and partially wrecking the switchboard. The damage is estimated at $75,000.

Denver was without light that night, but all those dependent for power and lighting on the local company were supplied in full the next day. In 24 hours service was completely restored.

It is well known when a vertical type of boiler is forced far above its rating—and this is not unusual at peak load—that there is a very considerable vibration, owing to the rapid circulation of water and violent generation of steam. Under such a vibrating strain the tubes, which are under considerable strain in ordinary operation, have been known to let go. We shall not, however, speculate as to the cause of the wreck until we have fuller information at hand.

Underground Transmission

Except in very special cases, trunk-line electrification must be accomplished by aerial transmission of current, or not at all, is the conclusion of a very able presentation of the advantages and disadvantages of underground transmission by William A. Del Mar in an article appearing at another page. Even were it possible to build railroad duct lines at the same cost as street duct lines, the volume of business per duct-foot on a railroad is so much less than in the case of an urban railway or lighting system, that the use of duct lines would be unsound engineering. As the matter stands, with duct lines costing from fifty cents to five dollars per duct-foot, the case in favor of aerial transmission is very strong.

A book by Henry Floy has recently appeared wherein the advantages of underground transmission and methods of constructing insulated cables for this purpose are set forth at great length. In his preface Mr. Floy says he realizes "the general lack of information with reference to the possibilities and advantages of subsurface electric transmission." This undoubtedly is true, but not in the sense intended by Mr. Floy.

As subsequently elucidated in the text of this work, it appears that the author confines his discussion of subsurface transmission to cables only, whose manufacture and performance up to 25,000 volts are fairly well understood. The dubious part of the whole subject is the construction and maintenance of the duct system under varying weather conditions and working under operating conditions different from the city duct work of central stations.

National Electric Light Association

In a year of unprecedented growth, it was natural to expect that the National Electric Light Association would have an unusual convention. It was a record-breaker in point of attendance, number of exhibitors, number of papers presented, and lastly, was favored by unusually fine weather. President Eglin is to be congratulated in closing with great éclat the most splendid year of the Association's work.

In going over a list of 60 odd papers, we find some good ones, and a few bad ones that ought not to have been presented.

"The Manufacture of Incandescent lamps," by S. E. Doane, *et. al.*, is a joke. With the utmost care this paper details the rudimentary manufacture of carbon lamps and ostentatiously states that "a large percentage of the various operations apply to all of the four types of lamps," mentioning carbon, metallized, tantalum and tungsten. Everybody knows the elementary steps of carbon-lamp making. What everybody wants to know is how tungsten lamps are made. We may possibly tell all about it in a later issue.

"The Grounding of Secondaries" will go over another year because the committee's recommendation not to ground over 150 volts was rejected on vote. Why the committee felt itself not bound to discuss the recommendation of the A. I. E. E. to ground up to 250 volts from neutral to outside is exceedingly difficult to say. We hope it will not require three more years to settle this tedious but important question.

"It is to be hoped that the committee will provide a kilowatt rating at some power-factor common in industrial work," was the significant wish expressed editorially in THE ELECTRICAL AGE over a year ago, and now, in a measure, fulfilled by the splendid presentation of reasons for such a specification in W. L. Water's paper on "Performance Specifications and Ratings." As is pointed out by the author, a machine designed for a lighting load of 100 per cent. power-factor usually has a relatively saturated field which cannot hold up voltage on a low power-factor. If such a machine were designed for normal load at, say, 80 per cent. power-factor, it would be larger (and cost more) and have an unsaturated field.

The report of the gas-engine committee was probably intended for the instruction of those not familiar with the subject, and is, therefore, disappointing to one who expects to find engineering data worthy of the attention of a national society.

For the most part the meter report is of that elementary character which will be welcomed in the small central station. It is the best text-book on the subject that we know of. A study of the questions answered for the committee by 161 companies shows that meter practice is not anywhere near uniform and that there is wide divergence of opinion as to important phases of it. The data are not worth much, except as they *show* this condition.

The discussion of the low-pressure turbine was chiefly marked by its brevity.

The report of the lightning protection committee contained nothing new, except to recommend thorough inspection of the protective outfit. Most of the recommendations may be found in preceding reports of this committee and of the A. I. E. E. Proceedings. One of the larger companies found the damage to transformers by lightning to be less than the fixed charges on its lightning-arrester investment. The more important technical papers appear in this issue elsewhere.

The Low Pressure Turbine

In last month's issue we pointed out the theoretical considerations which govern the yoking of a low-pressure turbine to an engine yielding a constant supply of steam.

In case the engine yields an intermittent supply of steam it is necessary to provide some means of equalizing the flow or to pass a steady supply of steam direct from the boiler.

In the latter case, it becomes necessary to use a reducing valve to bring the pressure of the steam down somewhere near the range of pressures for which the turbine is designed. It is usual to admit live steam in this way at a reduced pressure of about 20 or 25 lb. during the time that the machine is cut off from its supply of exhaust steam.

For the regulation of an intermittent supply of steam, such as comes

from a rolling-mill engine, steam hammer or hoist engine, it becomes necessary to use what is called a steam regenerator or accumulator.

The accumulator is really a large body of hot water which absorbs the intermittent heat from the engine's irregular exhaust, passing it over in a steady flow to the low-pressure turbine. In actuality, it consists of a very large cylindrical boiler shell, horizontally divided into two parts, each containing a like number of perforated, elliptical tubes in communication with the exhaust pipe of the engine. The exhaust steam enters the accumulator below the surface of the water.

The continual operation of the turbine passes the vacuum of its condenser on to the accumulator, so to speak, and reduces the pressure in the accumulator; with the result that a continual vaporization of water occurs in accordance with the well-known law of physics that the boiling-point, or temperature of vaporization, lowers with a decreasing pressure.

The accumulator for a 500-kw. turbine will be about 11 ft. in diameter by 30 ft. in length to supply regenerated steam for seven minutes after the stoppage of the exhaust steam. Obviously it is the cycle of intermittent exhaust which determines the possible size of the accumulator. It is equally obvious that there is a limit in size beyond which it is not economical to go, and the limit is not big. Not big enough to allow for the intervals of 20 and 30 minutes which frequently occur in rolling-mill work.

Consequently, it becomes necessary to provide another supply of steam if the low-pressure turbine is to be kept in continual operation. This necessity has given rise to what is now known as the mixed-flow turbine, which is a combination of low-pressure turbine and a high-pressure turbine, the whole forming a compact unit. The actual machine contains two sets of turbine wheels, one designed for high-pressure steam and another set designed for low-pressure steam, mounted on a common shaft in a single shell. The machine operates on either high-pressure or low-pressure steam, or simultaneous supply of both.

As an indication of the fuel economy introduced in manufactories employing non-condensing engines, we cite the installation by Messrs. Battu and Smoot at the International Harvester Company's works of a low-pressure turbine fed from a 42 by 60 rolling-mill engine consuming on the average 52,400 lb. of steam per hour, with an average of 64 lb. per indicated horse-power. The exhaust from this engine would generate 1510 h.p. at the switchboard and show on the same boiler plant a total of 2320 h.p. delivered for 52,400 lb. of steam or a steam rate of 22.5 lb.

The saving per year figures out $67,500 if we credit the fuel cost of turbine power to the fuel account of the mill, or, in other words, the installation of a low-pressure unit under such conditions pays for itself in less than a year.

It is surprising, therefore, in view of this acknowledged fact, that there is not a wider use of these machines in the States. In Europe they can be found in every country in mines, collieries and steel mills, driving electric generators, fans and pressure blowers. More than two hundred machines, chiefly of the Rateau type, are in operation, aggregating a round half-million kilowatts.

In this country the low-pressure turbine was introduced by the American Rateau Steam Regenerator Co., which was organized after the American patent rights were turned down by the Western Electric Co., which company had made a full investigation of the Rateau type of machines. The first machine, however, was built in the shops of the Western Electric Co. under contract to the American Rateau Co., which later became indebted to the Western Electric Co. Seeing that the machine was all that was claimed for it, the Western Electric Co. foreclosed on the old Rateau Company, thus obtaining the right to manufacture that type of machine under all Rateau patents granted up until the year 1907. Recent regenerator patents and mixed-flow turbine patents of Rateau are, however, not controlled by them.

During the last few years both the Westinghouse and General Electric companies have built successful turbines for this class of work, of both the low-pressure and mixed-flow type, aggregating perhaps 100,000 kw.. The Western Electric Co. has built in two years two machines of 500 kw. each. Just why the Rateau type manufactured by them should not be popular is rather hard to understand, as it is identical with the early types of machines built in Europe.

The Production of Mica in the United States in 1908

The total value of the mica produced in the United States in 1908, according to statistics compiled by the United States Geological Survey, amounted to $267,925. The production of sheet mica amounted to 972,964 lb., valued at $234,021, a decrease of 87,218 lb. and $115,290 from 1907. The production of scrap mica amounted to 2,417 short tons, valued at $33,904, a decrease of 608 tons and $8,896. The value of the imports into the United States fell from $925,259 in 1907 to $266,058 in 1908, or slightly less than the domestic production.

Production of Copper in 1908

The production of copper in the United States in 1908 was 942,570,721 lb. This is the largest production ever made, exceeding that of 1906 by 24,765,039 lb. and that of 1907 by 73,374,230 lb., or 8.4 per cent.

PRODUCTION OF COPPER IN THE UNITED STATES IN 1907 AND 1908.

[Smelter output, in pounds fine.]

	1907.	1908.
Alaska	7,034,763	4,438,836
Arizona	256,778,437	289,523,267
California	33,696,602	39,643,835
Colorado	13,998,496	13,943,878
Idaho	9,707,299	7,256,086
Maine	....	7,027
Massachusetts	....	7,863
Michigan	219,131,503	222,289,584
Montana	224,263,789	252,503,651
Nevada	1,998,164	12,241,372
New Hampshire	....	128,112
New Mexico	10,140,140	4,991,351
North Carolina	544,040	14,342
Oregon	518,694	271,191
Tennessee	19,475,119	19,710,103
Utah	66,418,370	71,370,370
Vermont	696,102	....
Virginia	57,008	25,087
Washington	122,263	162,201
Wyoming	3,026,004	2,416,197
Maryland, Alabama, and Georgia *a*	90,655	45,537
South Carolina, *b* Texas, *b* South Dakota *b*	....	
Missouri and unappotioned	1,299,043	1,580,831
	868,996,491	*c*942,570,721

a Georgia did not produce in 1908.
b Not reported in 1907.
c A portion of this total was reported by one company as electrolytic instead of blister copper. To compensate for the loss in refining there is added pro rata to the States concerned the approximate copper content of the bluestone recovered in the production of the electrolytic copper.

Refined Copper

The production of refined new copper of domestic origin in 1908 was 875,849,129 lbs., an increase of 11.6 per cent. over the production of 1907. The total output of refined copper (exclusive of domestic scrap, etc.) by domestic refineries in 1908 was 1,094,700,123 lbs. The apparent consumption of refined new copper in the United States in 1908 was about 480,000,000 lbs.

The Use of Reactance Coils in Generating Stations

P. JUNKERFELD

The subject of protective devices for the transmission system and for the translating apparatus in substations has been pretty thoroughly worked out and the results are apparently quite satisfactory. We feel reasonably certain that the protection of that part of the system is well in hand. With the generator itself, however, the condition is not so reassuring. A few breakdowns within or close to the generators in some of the larger stations have resulted at times in such severe destruction to the generator that the advisability of using reactance coils in this connection is receiving serious consideration.

That such coils of proper design will offer at least partial protection is, of course, recognized, but their adoption in large installations is slow because of a natural prejudice against adding any so-called contraptions, at least before their satisfactory operation has been proven.*

The condition which gives rise to the demand for reactance coils is, as is well known, the very excessive instantaneous short-circuit current of these high-speed, low-frequency, high-voltage turbo-generators. In such generators, with their relatively large pole pitch and consequent low self-induction, this instantaneous short-circuit current may be as high as fifty times full-load current with a power factor possibly over 50 per cent. There may, therefore, be an enormous transfer of energy. It is several seconds before this current has died down to the sustained short-circuit current of about three times full-load amperes. A reactance to limit this instantaneous short-circuit current to about ten times full-load current would so reduce its power factor, and therefore the energy, that the effect would be comparatively harmless. The injurious strains on the armature conductors, and especially on the end turns, would also be reduced to a comparatively safe intensity. Incidentally, such coils will tend to lessen somewhat the shock on a generator when it is poorly synchronized, but this advantage has not sufficient weight to be a factor in the question.

The introduction of such coils in existing installations is no easy matter, and this is, perhaps, another reason for the hesitancy in their installation. For a generator of about 10,000-kw. capacity each of the three coils (in a three-phase machine) would require a cubical space of approximately five feet per side for proper clearance, or, roughly, 125 cu. ft. With a generating voltage of approximately 10,000, each coil would have 110 to 150 turns. It could be of insulated cable, if properly ventilated, or of bare cable wound on porcelain insulators. In either case the core of the coil would probably be of concrete. The coils must be very rigidly anchored, as they will be subjected to severe strains when large currents flow through them.

The object of the coils is, of course, to increase the reactance of the generator circuit and thus reduce the instantaneous short-circuit current. This would be acomplished by connecting them either in the phase leads, as in Fig. 1, or in the neutral ends of the armature winding, as in Fig. 2. In the phase connection the insulation of the coils must withstand at least double normal potential, but the generator is also protected against high-frequency surges which may come in over the bus bars. Should a breakdown occur within the armature or in the conductors between the armature and the coils, in this phase connection the coils would not reduce the current from the generator itself but would offer protection against excessive current into the fault from other generators that may be operating in parallel at the time. If connected on the neutral side, which is, of course,

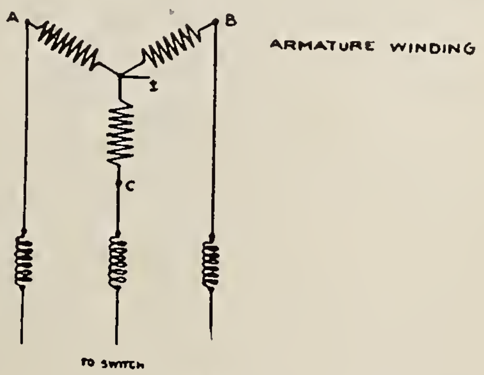

Fig. 1

possible only in Y-wound generators, protection against its own excessive current is afforded for breakdown within the armature. Where the neutral is grounded without resistance the insulation need be only sufficient for the reactive electromotive force across the coils. If the neutral is grounded through resistance the rise of potential above ground may be several thousand volts at the coils, depending on the value of the resistance. It is possible that the installation of reactance coils will render neutral resistances unnecessary. Where the neutral is not grounded the insulation of the coils must still be fairly high even if connected as in Fig. 2.

If the neutral connection is used with existing generators it will be necessary to make some structural changes, as in these generators the neutral ends of the armature coils are joined within the armature frame. All three of the neutral conductors must be brought out, and this will require more or less changing in the arrangement of outer conductors.

The loss in efficiency due to these reactance coils need not be high; in fact, it could be well below one or even one-half of one per cent. and the regulation drop would not be seriously increased—perhaps two per cent. If the coils could be readily installed and if they introduce no weakness themselves this small sacrifice of efficiency and regulation should not stand in the way of their adoption.

The protection of a damaged generator against the influx of excessive current from without naturally suggests the installation of suitable coils in the bus bars so as to sectionalize the through buses. Such coils could be normally short-circuited by means of an automatic switch that will open when an excessive current flows, provided such a switch could be made to open quickly enough. The impedance of such coils could have a value to limit the current through them to, say, the full-load current of one generator; but this is a matter to be determined best for each system. In fact, the entire question of reactance coils, whether to use or not to use them, especially in the smaller stations, is a matter to be determined by local conditions. Ordinarily, such coils should not be adopted unless their need is apparent, as they are a step away from simplicity. In large power, low-frequency and high-speed generators (water or steam-turbine driven) they are probably advisable, but 60-cycle generators unless of very high speed (over 1200 r.p.m.) have

* N. E. L. A., 1909.

sufficient self-induction in the armature winding without them, as have also engine-driven generators of 25 cycles. Reactance coils have been installed on the generator leads of the 3750-kw. and 6000-kw. turbine-driven units of the New York, New Haven and Hartford Railroad in the station at Cos Cob with apparently satisfactory results. A trial installation is also under way in Baltimore and another on one unit in Chicago.

Some engineers, notably the Germans, use reactance coils at the station end of transmission cables. Such use on transmission lines has long been common practice in connection with lightning arresters on overhead lines, but on underground cables the fear of resonance has prevented their general adoption.

This subject has arisen as a result of development. In the earlier years builders of electric generators desired prime movers of higher speeds in order to reduce cost of their generators. With many of the latest prime movers (steam turbines) the speeds have been increased to a point where in the present state of the art the generators suffer in reliability. In other words, it seems that if we desire the best steam economy in the turbine we must accept some sacrifice in the reliability of the generators. This sacrifice can be reduced by the installation of reactance coils, but as this course is in some respects a step backward, even though at present a possible necessity, it should receive serious consideration.

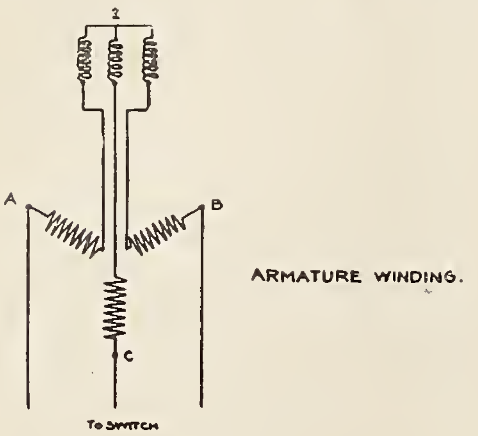

Fig. 2

Practical Design of Reactance Coils for Turbo-Generators

A. S. LOIZEAUX

The purpose of this paper is to give other companies the information which the Baltimore company has obtained in designing, testing and operating reactance coils for a 5000-kw., 13,000-volt, 25-cycle, 4-pole General Electric 750-r.p.m. turbo-generator. These coils were designed in the fall of 1908 and placed in operation December 31, of that year.*

Type of Coil:

In designing reactance coils for turbo-generators it is imperative that large cooling surface should be obtained. Two general types of coil are feasible: flat or pancake coils, with cooling spaces for air or oil between the coils, and solenoids, with cooling spaces between the concentric layers.

Cooling:

Either oil-cooled or air-cooled coils may be constructed, but when the coils are installed on the neutral ends of generator windings, and especially when the neutral is grounded, the coils require only a small amount of insulation and may be readily made air-cooled without air blast. For coils on the outside windings of high-voltage generators, oil-insulated construction would possibly be better.

* N. E. L. A.

Iron Cores:

If iron cores were used in building reactance coils for turbo-generators, sufficient iron would have to be employed to insure that the flux did not pass the saturation point under short-circuit conditions, because if the iron was saturated, or oversaturated, the choking effect of the coils would be limited at the very time it was required. Air coils have no core loss; their copper loss with the same current density would be greater than in coils with iron cores, because of the greater length of conductor required. The copper loss in a coil can of course be reduced at will by using larger cross-section of copper. It is doubtful to my mind whether coils with iron cores will prove practical; this is an interesting question for discussion.

Shape of Coil:

The greatest amount of reactance for a given amount of material in a coil without iron is obtained by arranging conductors so that their cross-section will be circular, as this makes the field from each turn cut the maximum numbers of turns. These proportions are objectionable in practical design for mechanical reasons, but an approximation is obtained in a coil where the section of conductors is rectangular and approaches a square. This design is much more economical of material than a long coil of a few layers.

The reactance coils for the Baltimore turbo-generator were made in the solenoid form, air-cooled, with ventilating spaces between each layer of cable, as shown in Fig. 1.

Calculation of Coils:

To determine the number of turns, Mr. E. J. Berg's formula for a coil whose reactance would be 6 per cent. of the total impedance of the generator was used.

$$T = 110 \sqrt{\frac{E}{I \times d}}$$

where T = number of turns, E = generator volts, I = full-load amperes, d = mean diameter of coil in inches. This formula becomes for this case

$$T = 110 \sqrt{\frac{13{,}000}{222 \times 36}} = 141 \text{ turns.}$$

The coils were built with 144 turns each, and the reactance by test was found to be 6.9 per cent. The coil had a cross-section of conductor much more nearly square than covered by the formula, and the test would indicate that the constant for this shape of coil should be 95 instead of 110.

Core Construction:

Concrete cores were cast in the form of a hollow cylinder, with grooves provided for wooden cleats on the outside of the cylinder. No iron was used for reinforcement. Subsequent tests proved that iron would be decidedly objectionable, and that brass would not be objectionable provided that no closed metallic circuits were made in which current could circulate. The form for casting the cores was made of sheet iron and wood: the wood being soaked in water, previous to filling the mold, to prevent cracking of the concrete by the expansion of the wood. After removing the cores from the mold they were kept in wet sand for a week to increase their strength. Bolt holes were molded in the core at the proper points for supporting the windings.

Cable:

The cable used for winding these coils is 250,000 circular mils stranded copper with three-thirty-seconds-inch varnished-cambric insulation and braid finish, designed for 1000 volts working pressure. This size of cable for 222 amperes rated load gives a current density of 1125 cir. mils per ampere. The common cable compound should not be used in cables for reactance coils. In this case the compound melted out of the braid and clogged some of the ventilating spaces.

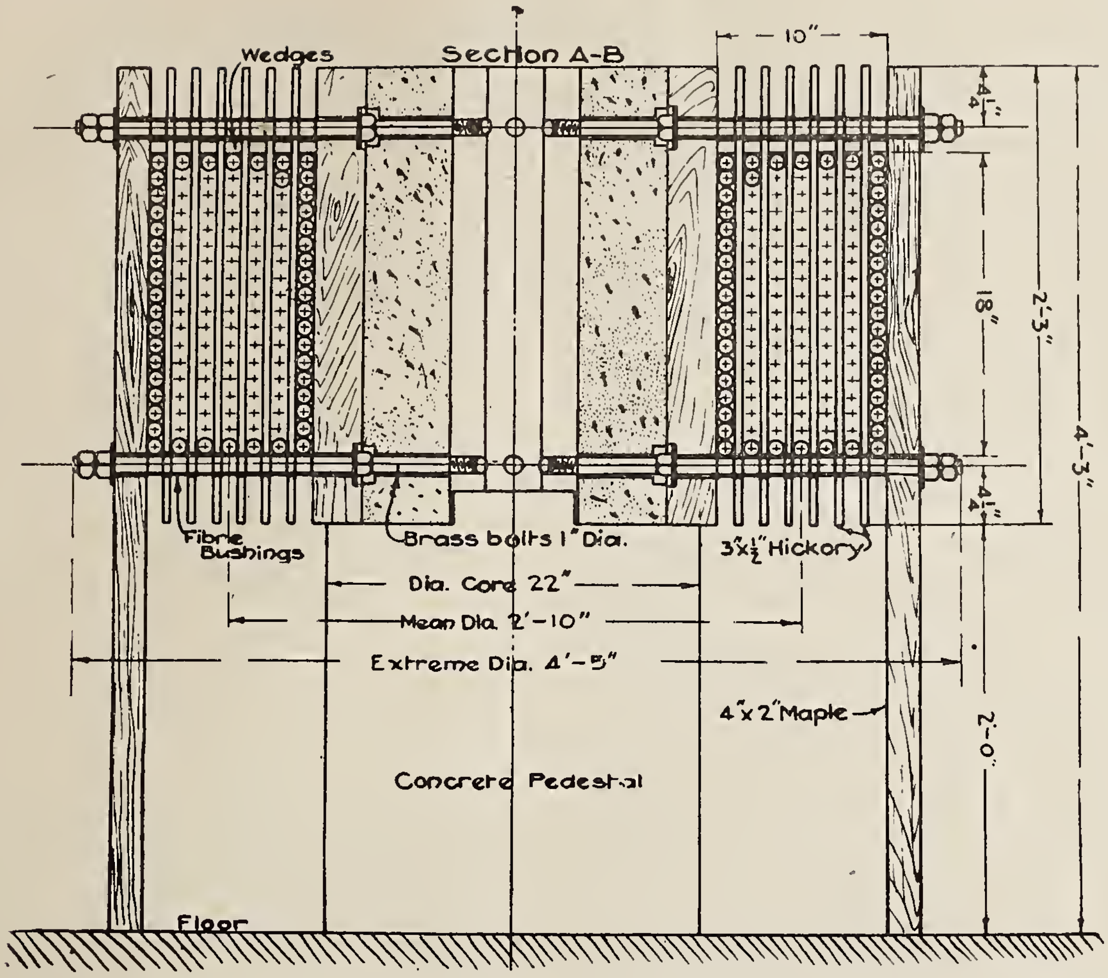

Fig. 1—ELEVATION

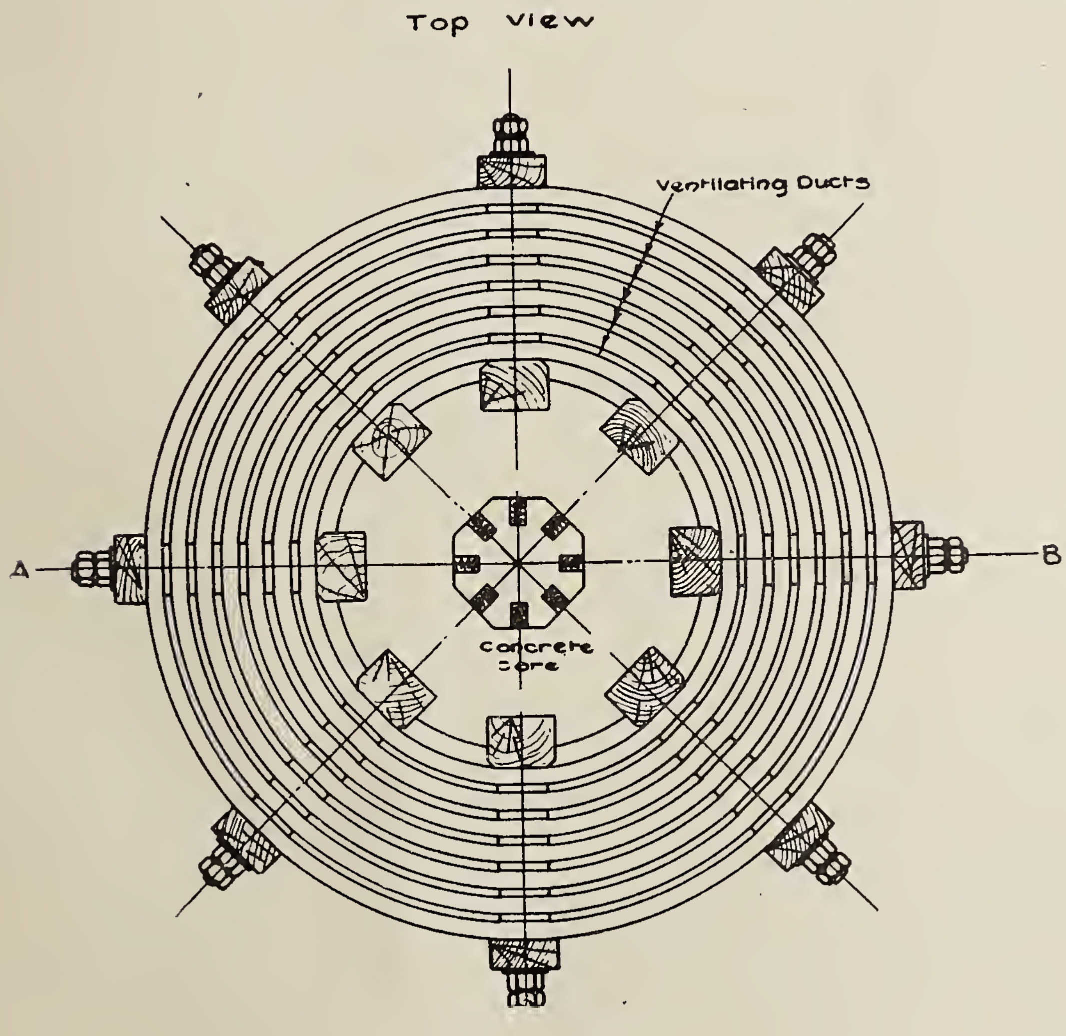

Fig. 1—PLAN

Bolts:

A few iron bolts were installed to determine their heating effect. They very quickly became so hot that the wooden spacers were set on fire. Wooden rods were substituted temporarily, and brass rods afterward installed, as it was found that, with a temperature rise of 50° cent. in the coil, brass rods had a rise of only 15 degrees. This is an interesting observation, as it was expected that eddy currents in brass bolts would cause excessive heating.

Assembling.

During winding, the core was mounted on a mandrel between horses, the bolts were rigidly secured to the core by tightening the nuts on the inside and outside of the core, and the cable wound on the core in eight separate layers of 18 turns to the layer, with a space of 0.5-in. between each of the concentric layers thus formed. These spaces were made by inserting hickory strips 3 in. wide and 0.5-in. thick at 8 points around the circumference; that is, 45 degrees apart. The entire coil is bound together by 16 brass bolts, 8 at the top and 8 at the bottom, which pass through all of the wooden supports and spacers. After completing the coil the nuts on the inside of the core were removed, to relieve the core of tension and let the tension strength of the windings take up this strain. The ends of the cable in each coil should be securely fastened, to prevent any slipping of the cable when under strain.

Mounting:

The coils are mounted on concrete pedestals, which support the cores. The heavy oak sticks on the outside of the coils are made of the proper length to extend to the floor, and thus support the windings on the outside. As mounted, the three coils occupy a total space of 75 sq. ft. They are mounted 80 ft. from the generator and close to the ground bus to which they connect, this being the most available location. The feasibility of mounting the coils one above the other was considered in order to reduce floor space required. This was not carried out, because it was feared that the upper coils would become overheated, due to receiving air already heated from the coils below.

Electrical Location.

Fig. 2 shows the location of reactance coils in the neutral of the generator circuits, and shows the disconnecting switches used. This arrangement of switches enables any coil to be disconnected for repairs or in case of trouble, without shutting down the generator.

Ventilation:

The spacers above mentioned form vertical passages on both sides of every layer of cable, giving a chimney effect, which produces rapid circulation of the air. This, or some equally efficient means of cooling, is absolutely necessary, as the full-load temperature rise in the hottest part is 50° cent.

Temperature Rise:

The temperature observations of these coils were made at the top of the windings, between the outside, middle and inner layers, the highest rise being found between the middle layers.

The temperature rises mentioned are the maximum observed. (See Fig. 3.) We have not had 50 per cent. overload on the generator for a sufficient length of time to get a maximum rise on the reactance coils, but this service would undoubtedly produce a temperature higher than ordinarily used, and it may be found advisable under overload conditions to cool the coils by air blast. It might be advisable in building coils for turbo-generator without air blast to allow more copper than 1125 cir. mils per ampere as in the present case, in order to reduce the copper loss, increase radiating surface, and therefore reduce the temperature rise.

Losses in Operation:

The loss during full-load operation, as indicated by a wattmeter with cur-

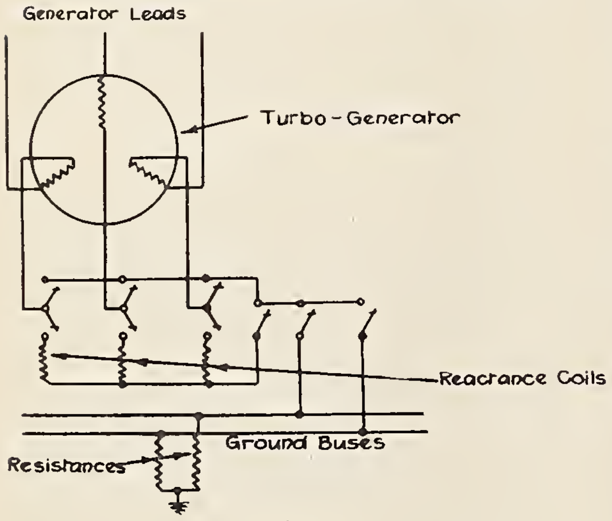

Fig. 2

rent and potential transformers, was 12 kw. per coil of 144 turns, which is 0.72 per cent. of the power delivered by the generator. This loss seemed too high for economical operation, and the outside layer of 18 turns was removed from the coil, leaving 126 turns. The apparent loss by wattmeter reading was then 9 kw. To check the wattmeter readings, which were regarded with suspicion because of the extremely low power factor of 3.15 per cent., direct current was passed through the coils and adjusted to give a constant temperature rise. The volt-amperes or watts then gave the actual loss corresponding to the given temperature rise. This direct-current measurement was repeated for several different temperatures and the results plotted in a curve (Fig. 3). Thermometers were left undisturbed and temperature logs taken in regular operation. A curve giving the relation of load and temperature was also plotted, and, when used in connection with the temperature-loss curve, gives the loss for any load. This method indicates a loss of only 2.6 kw. per coil of 126 turns as compered with the wattmeter reading of 9 kw., and an ohmic loss of 2.46 kw., which shows that the loss in the coils is almost entirely ohmic. There is no doubt that some loss occurs in eddy currents in conductors, due to the very powerful field, but the measurements were not sufficiently refined to state that the indicated difference of 0.14 kw. per coil is a measure of eddy-current loss. The total loss for coils with 5 per cent. reactance is 0.156 per cent. of the generator output, which is very much less than the amount mentioned by Mr. Junkersfeld as permissible.

Cost:

The cost of opening the generator neutral and taking three cables to the terminal block of the generator was $134. The cost of labor and material in extending neutral leads 80 feet to reactance coils was $93. The total cost of three reactance coils, complete, was, for drawings, $32; for labor, $182; for material, $1,059; making a total of $1,273. The disconnecting switches have not been installed as yet, and will be additional to the above-mentioned costs.

The total cost of providing reactance coils is about 3 per cent. of the cost of the electric generator, and the loss in the coils is about 0.16 per cent.

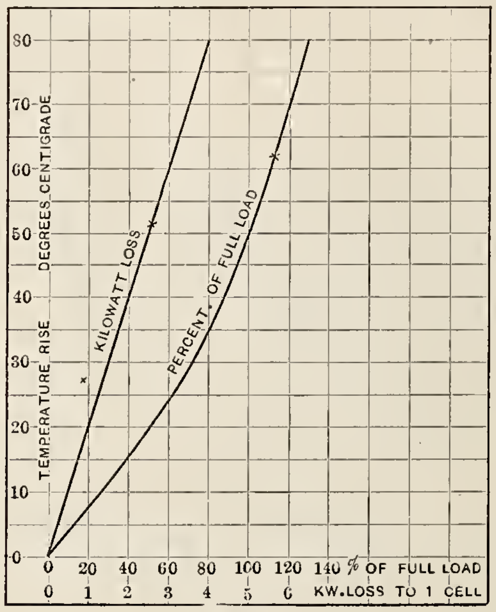

Fig. 3

of the output. Both of these figures are so conservative that reactance coils may be considered an economical insurance against damage due to short-circuit.

Strength to Resist Short-Circuit:

If a short-circuit should occur on a circuit equipped with reactance coils, there would be a heavy strain on the coil, due to the repulsion of the windings. In a circular coil, as distinguished from an elliptical coil, the strain in a radial direction is resisted directly by the tensional strength of the conductor without any tendency to deform or change the shape of the coil. The strength of the conductor would doubtless be sufficient under all practical conditions to stand this strain successfully. It therefore remains in

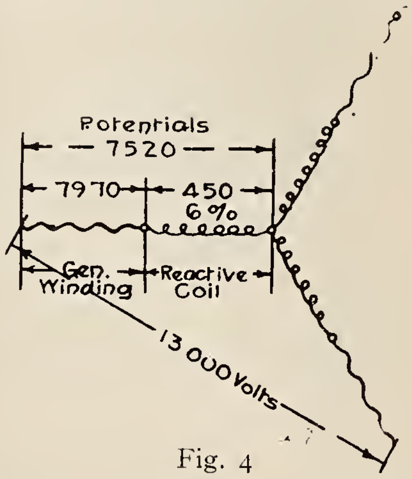

Fig. 4

the design of a helical coil of circular form to provide sufficient strength in the winding supports to take up the strain in the axial direction. In the Baltimore coils this is provided for by heavy oak sticks on the inside and outside of the winding and by hickory separators 3 in. by 0.5-in., as before described. Brass bolts pass through all of these tension pieces, and wedges are driven securely between the bolts and the upper layer of windings, to hold the same rigid.

By calculation it was found that if wooden rods are used the weakest part of the construction is the crushing of the wooden rods under the hickory separators. This strength is 1250 lb. per separator. By using brass bolts this strength is many times increased, and the weakest point is the shear of the separators with the grain, which amounts to 4000 lb. per separator, or 96 tons for an entire coil.

Protection in Case of Short-Circuit:

From assumed value of generator resistance and reactance, it appears that the 5 per cent. reactance coils would limit the short-circuit current to approximately 13 times full-load current, and would give a power factor for the complete circuit of 13 per cent. This means that the torque on the generator under short-circuit conditions would be less than twice full-load torque, and therefore safe.

Data on Reactance Coils:

The following data are put in tabulated form for reference and refer to the coils after removing one layer, as above described:

Number of turns on each coil	126	
Length of conductor in each coil	1105	feet
Non-inductive resistance at 40 degrees Centigrade	0.051	ohms
Drop across one coil at full load, 222 amperes, 25 cycles	373	volts
Impedance full load, 222 amperes, 25 cycles	1.68	ohms
Impedance full load, 222 amperes, 25 cycles	5	per cent
Total loss per coil, full load, 222 amperes, as determined by thermal test	2.6	kilowatts
I2R loss, 222 amperes	2.46	kilowatts
Power factor of reactance coil	3.15	per cent
Loss in 3 reactance coils in per cent of generator load	0.156	per cent
Short-circuit current in terms of full-load current	13.4	
Power factor of generator circuit under short-circuit conditions with reactive coils	13	per cent
Short-circuit torque in terms of full-load torque	1.8	

The Difficulties of Underground Transmission for Trunk Line Electrification.

By WM. A. DELMAR.

There exists an impression among some engineers, whose experience does not cover the field of trunk-line electrification, that the most important considerations affecting a decision upon the relative merits of overhead and underground transmission, concern the cables themselves and that the ultimate choice depends upon the relative cost and reliability of bare and insulated conductors.

Experience, however, shows that the decisive factor is not the type of cable, but the type of cable support, the real difference between the two systems being that in the overhead system the cables are supported occasionally, and where there is plenty of room, and that in the underground system the cables are supported continuously and where the space is restricted.

Except for voltages over 25,000, there is no doubt whatsoever of the practicability of making good insulated cables, a fact well known to those who have followed the progress of the cable industry during the last decade. Insulated cables, of course, are more expensive than bare ones, and this undoubtedly influences, to some extent, the choice of transmission system for railroad electrification, but it is by no means the deciding factor.

The deciding factors are the excessive difficulties and costs of constructing and operating duct lines along railroads. These facts are presented below under two headings, "Construction Difficulties" and "Operation Difficulties." After a careful consideration of what follows, the reader will be led to the conclusion that, except under extraordinary conditions, the policy of trunk-line railroad engineers will be to employ aerial transmission wherever possible, using underground transmission only where local conditions, such as insufficient clearances, or æsthetic considerations do not permit the adoption of the former system.

The objections to underground transmission are as follows:

CONSTRUCTION DIFFICULTIES.

(1) Owing to the right-of-way being usually on made ground, excessive quantities of concrete and reinforcement are required to make a reasonably strong duct construction.

(2) Owing to the width of the right-of-way being usually very restricted, it is necessary to shore-up tracks in order to excavate close to them.

(3) Owing to the vibration caused by heavy trains, it is necessary to bury the conduits at a great depth, first to avoid undue stresses on the conduit, and second, to avoid crystallization of cable sheaths.

The injurious effects of train vibration on the cables of the Manhattan Railway and Toronto Electric Light Co. are so well known as to need no description.

In order to have the conduits below frost level, the depth of ballast must be neglected, as it has been found that with stone ballast on top of the ground, the frost penetrates the ground about as far as if the ballast were not there, unless the ballast is very dirty.

(4) There is considerable difficulty in obtaining net results from labor where there are continual interruptions by trains. On a busy section a duct construction gang engaged for ten hours can possibly work two full hours.

(5) Owing to the right-of-way being often quite low and in many cases alongside of rivers, duct construction is likely to be seriously impeded by the flooding of trenches.

(6) Where the right-of-way shows signs of settlement, as, for example, on marshy ground, continuous piling is necessary to support the ducts. This involves the use of the track for construction purposes for long periods, and thereby not only impedes, but also endangers traffic.

(7) Duct line construction generally involves interference with signal and interlocking apparatus, thereby introducing danger and expense.

(8) Bridge abutments, bridges, culverts and, in fact, all special right-of-way construction present complicated problems which can be solved only at great expense.

OPERATION DIFFICULTIES.

(1) Owing to the right-of-way being usually on made ground, duct lines settle and crack, injuring the cables in them and preventing the removal and replacement of injured cables.

(2) Owing to the great depth of splicing chambers necessitated by the circumstances enumerated above under (3), they are often full of water and cannot be cleared for repairs without pumping water out of as much of the system as is at the same level, a process which may take many hours to complete, possibly leaving traffic paralyzed during that time. Drainage is usually out of the question, owing to the absence of any kind of drainage system below the surface system.

(3) The great depth of chambers requires the use of long narrow chimneys connecting the chambers to the surface of the ground. This makes it almost impossible for employees to escape from chamber in case of trouble.

The operation of cable splicing in underground system is always accompanied by more or less danger. There are many cases on record where cable breakdowns have taken place while men were working in splicing chambers, where, on account of the confined space, it is practically impossible for a man to get out of range of the heat of a short circuit. Such a case occurred in the conduit system of the Long Island Railroad at Woodhaven Junction, July 12, 1906. There were men working in a splicing chamber when a great sheet of flame shot out of the manhole, and three men were seriously burned, one being terribly injured.

The cables were out of use for eighteen hours on this occasion and much of the delay was caused by the objection of the men to enter the chamber.

(4) Where improvements are made involving the raising of the right-of-way, such as, for example, in eliminating grade crossings, ducts laid previous to the improvements become so deep that they are practically inaccessible for repairs and splicing chambers are correspondingly dangerous on account of their distance from the surface.

(5) The existence of water in low splicing chambers renders the cables particularly liable to electrolytic corrosion. This is a very serious matter where the grounded return is only a few feet away, as must inevitably be the case on a railroad. Electrolytic trouble cannot be reduced by grounding the cable sheaths to the track rails, as where electric signals are used, connection to the track rails is not allowable.

RELIABILITY OF AERIAL CONSTRUCTION.

Well-constructed aerial lines are more reliable than underground lines for the following reasons:

(1) Air and porcelain insulation are the most reliable known. Air

automatically repairs itself in case of puncture, and porcelain insulators are easily replaced, damage to them being occasional and local.

(2) All parts being visible, impending and existing troubles are easily located.

(3) Repairs are less frequently required on aerial than on underground lines.

(4) Repairs are more easily made. This is due to the accessibility of the wires and to the absence of repairs to insulation and sheath as required in underground work. The fact that there is no pumping of water from low splicing chambers and less danger in working also count strongly in favor of aerial lines.

(5) Non-spreading of trouble. Trouble is almost invariably confined to one spot on a single circuit, which is quite the reverse to what happens in underground systems.

Mr. H. W. Buck, whose experience with transmission lines is very wide, said at a recent hearing of the Public Service Commission: "I have had experience in the operation of both types of transmission and should consider the overhead system as very much more reliable for continuous service, when well constructed, than the underground system." He gave as reasons for his view, the higher factor of safety of insulation, ease of locating breakdowns and the non-spreading of trouble.

Trouble has been experienced on some transmission lines from the effects of lightning. This experience has been due almost invariably to inadequate lightning protection and to the use of wooden poles. Improved methods of protection are doing much to reduce the occasional troubles caused by lightning. It is, perhaps, treating an important subject rather lightly to thus, in a few words, dispose of lightning as an objection to aerial transmission. Considered from the broad standpoint, this is not so. Lightning is a source of trouble, but the trouble is not great enough to figure as a factor against overhead lines, except under very unusual conditions.

Low Pressure Steam Turbines

C. H. SMOOT

The first low-pressure turbine to run on the exhaust of reciprocating engines was designed by Professor Rateau in 1901 for installation at the Bruay mines in France.*

In 1902 this plant was put in operation and has been running successfully ever since.

In conjunction with this turbine, Professor Rateau installed one of his steam regenerators, connected between the hoisting engine, which supplied steam for the turbine, and the turbine, to equalize the flow of steam to the turbine.

The Bruay turbine has an output of 300 electrical horse power.

Since this time Professor Rateau and his associates have introduced a large number of low-pressure turbines, working both with and without steam regenerators, in numerous industrial works in Europe.

At first the most promising application of the low-pressure turbine was to use steam from highly inefficient non-condensing engines, which were found in steel mills and mine hoists.

After the application of turbines to inefficient non-condensing engines had been thoroughly developed, its field of employment was extended until at the present time low-pressure turbines are being installed on efficient power-producing engines in railway and lighting plants.

It is greatly to the credit of Professor Rateau to have been the first to thoroughly appreciate the advantage of the turbine as a low-pressure engine and to have made practical its application to intermittent fluxes of steam through his invention of the steam regenerator.

It has now been thoroughly established that the most efficient possible steam engine is a compound unit consisting of a reciprocating engine, acting between boiler pressure and approximately atmospheric pressure, exhausting to a low-pressure turbine, which in turn discharges to the condenser.

Were it not for the fact that high-pressure turbines in large sizes are vastly cheaper than reciprocating engines, it would be a safe prediction that all future plants would include turbines and engines.

It is still a mooted question, however, whether the greater cost of combined engine and turbine plant over that for turbine plant alone is authorized by the increased economy.

In any event, however, existing plants equipped with reciprocating engines will show improved economy by running them non-condensing and installing low-pressure turbines.

The results obtained when low-pressure turbines are employed to compound reciprocating engines, replacing that portion of the engine working between atmosphere and vacuum, are very striking. It was not until the low-pressure turbine had been commercially developed that engineers fully realized the significance of the fact that the available energy per pound of steam between 150 lb. boiler pressure and 28 in. of vacuum was cut practically in halves by the line of atmospheric pressure.

This fact appears almost like a discovery, because reciprocating engines have heretofore been wholly incapable of utilizing efficiently the energy below the atmospheric line. To obtain the expansion in an engine which can be readily reached in the turbine would require an enormous cylinder, whose friction would consume a large portion of the available energy. The turbine, however, can utilize as effectively the energy between 26 and 28 in. of vacuum as it can utilize the energy between atmospheric pressure and 5 lb. below.

FIG. 1

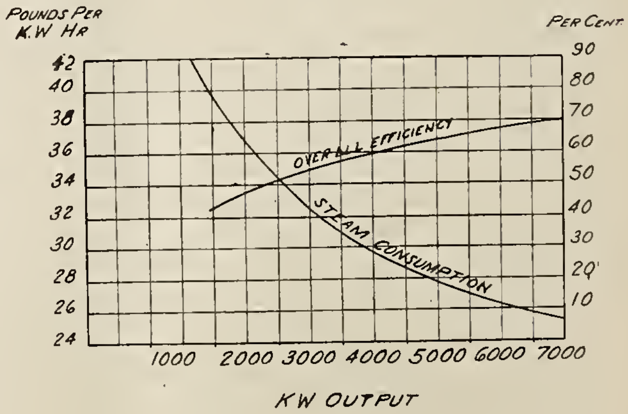

Fig. 1, gives the manufacturers' guaranteed steam consumption curves for a 7000-kw. low-pressure Rateau-Smoot turbine, running at 28.5 in. vacuum with an admission of 16 lb. absolute. At 7000-kw. such a machine will be guaranteed to deliver one kw.-hr. at the switchboard for 25.7 lb. of steam.

*N. E. L. A.

An investigation of the steam consumptions obtained when such a turbine is used to compound high-pressure non-condensing engines will prove of interest. The following table shows the steam consumption, efficiencies, *et cetera,* for each of these two units. The figures taken for the steam consumption in both cases are rated very conservatively for machines of large power, the turbine being of 7000-kw. capacity and the engines of over 2000 kw. each, several of which could be used in conjunction with a single turbine.

Boiler pressure, 200 pounds, no superheat
Vacuum, 28.5 inches on 30-inch barometer

	Pounds Steam Pressure Absolute		Theoretical Steam per Kw-Hour	Steam per Kw-Hour at Switchboard	Combined Efficiency of Engine and Dynamo	Steam per Indicated H.P.-Hour
	Admission	Exhaust				
Engine	214.7	16	18 lbs.	27.7 lbs.	65 per cent	23.4 lbs.
Turbine	16	0.75	17.8 "	26.6 "	67 "	....

The question of the most suitable intermediate pressure for engine exhaust and turbine admission is not so important as it might seem from a cursory consideration. The pressure giving the maximum efficiency for the whole plant is obviously the pressure that allows approximately equal efficiencies of heat transformation into power for engine and for turbine.

In the case of highly inefficient engines, however, such a condition can never be reached, and the intermediate pressure giving a maximum output from the whole plant should be taken as high as the condition under which the engine is working will permit. This latter condition is generally the case in engines working in steel mills doing highly intermittent service, for here, at the very best condition, the efficiency of the engine is always lower than that of the turbine.

The type of engines used in central stations, however, when exhausting in the neighborhood of atmospheric pressure, will show an efficiency practically equal to a low-pressure turbine, consequently very little difference in the plant efficiency will be made if the intermediate pressure is taken anywhere from 3 or 4 lb. below atmosphere to 15 or 20 lb. above. The reason for this wide range in pressure is to be found in the fact that the efficiency curve for both engine and turbine has a very flat top within this range, showing but slight rise or fall between either extreme.

CONDENSING APPARATUS

Since low-pressure turbines work efficiently on high vacuums, it is well worth while to investigate thoroughly

Steam per kilowatt from combined

plant $= \dfrac{1}{\dfrac{1}{27.7} + \dfrac{1}{26.6}} = 13.6$ lb. steam

per kilowatt-hour.

The combined mechanical efficiency of heat transformation into electricity represented by these two units working in conjunction is approximately 66 per cent., after allowing for all losses in turbine, engine and dynamo.

This combination of turbine and engine represents the very highest efficiency possible to obtain in any kind of steam engine, since it places to best advantage the reciprocating engine and the turbine, neither one of which can, unaided, accomplish the same result. The figures entering into these calculations are taken conservatively, and it is believed that the rating given to the reciprocating engine of 23.4 lb. per indicated horse-power hour compound non-condensing is a figure readily obtainable.

In Fig. 2 is a logarithmic plot of the available energy in steam for given admission and exhaust pressures. A straight line passing from the pressure at the throttle to the pressure of the exhaust intercepts the central scale of the corresponding quantity of steam per unit of power available in the steam. This figure, divided by the efficiency of the engine, gives the quantity of steam per unit of power developed. The formula from which this plot was made was originally developed by Professor Rateau from the entropy diagram and published in many of his papers on the subject of steam turbines.

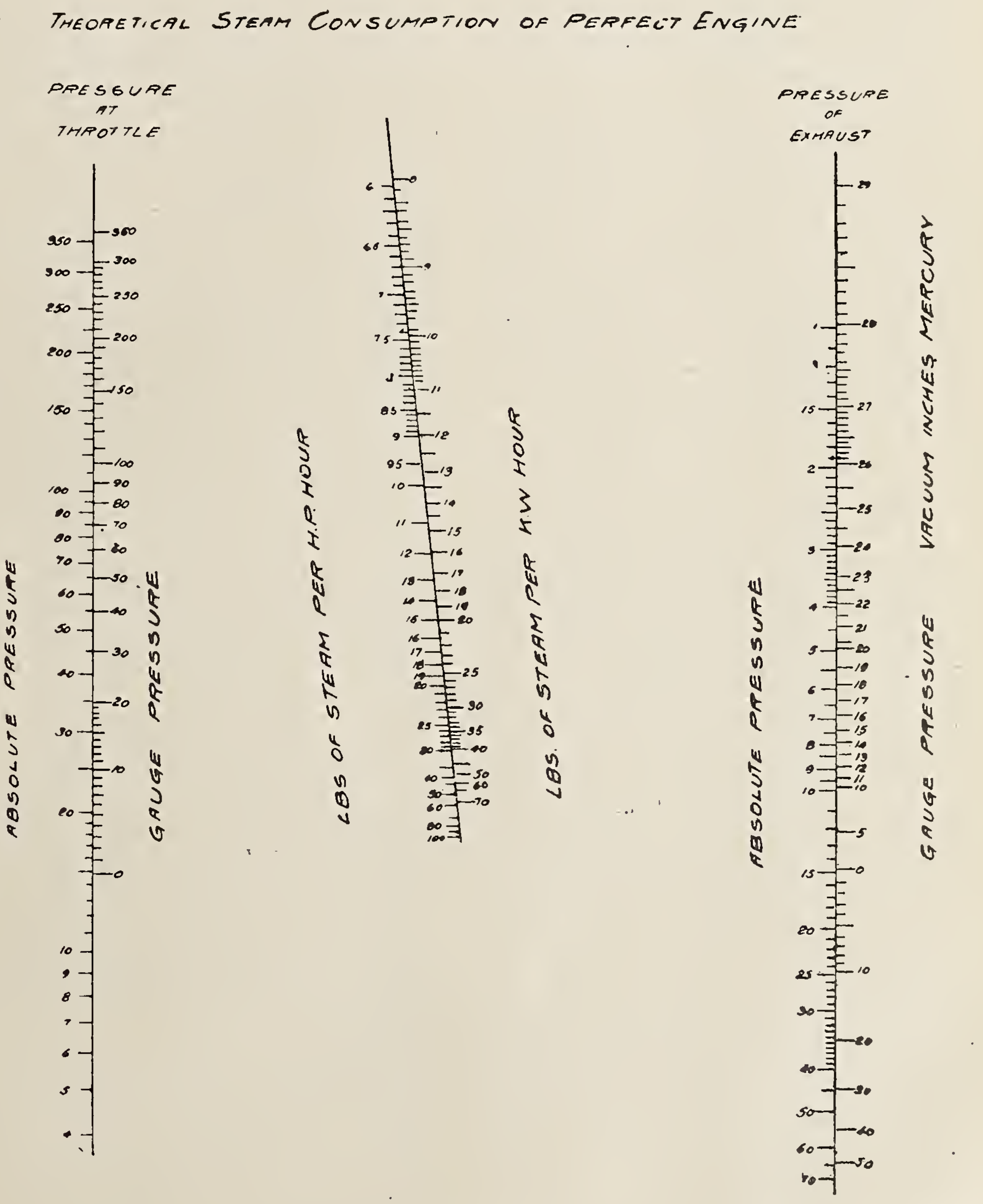

FIG. 2

the vacuum of maximum economy, putting on one side the cost of obtaining the vacuum and on the other the economy resulting in the turbine.

With barometric condensers, no real difficulty is encountered in obtaining a vacuum of 28.5 in. with water under 70° fahr., and similar results can be obtained with a surface condenser, provided a large water supply is available which does not require a high lift to reach the condensing vessel.

To obtain a high vacuum with either type of condenser, dry air pumps are essential.

When working on vacuums over 28 in., because of the low temperature of the steam, barometric condensers require much less water than surface condensers, since, in a well-designed barometric condenser, the water discharged may be within one or two degrees of the temperature of the incoming steam, thus utilizing practically all of its heat storage capacity. A surface condenser, on the other hand, when reduced to practical dimensions, requires a much larger difference in temperature between the discharged water and the entering steam, and consequently more water to carry away the heat.

The features of the condenser, which, from a practical point of view, limit the obtainable vacuum, are—in the barometric type, the air pump capacity; and in the surface condenser, the quantity of water.

Under fairly favorable conditions, the power expended to maintain a vacuum as high as 28.5 in. on a low-pressure turbine does not exceed 5 per cent. of the turbine output.

STEAM REGENERATORS

A discussion of the low-pressure turbine is not complete without reference to the Rateau steam regenerator, which has made feasible the application of low-pressure turbines to intermittently operating engines.

The regenerator consists of a cylindrical vessel, containing water which is kept in intimate contact with the steam supply, and through the variations in temperature of steam attendant to corresponding variations in pressure serves as an accumulator of heat through increasing and decreasing the temperature of the body of water.

As the pressure of the steam rises within the vessel, the temperature of the water also rises, accomplishing, therefore, the storage of heat in the water through the condensation of steam; and *vice versa*, when the steam pressure falls, the temperature of the steam becomes less and the water gives off the heat which has been previously stored, in the form of steam.

The effect of the steam regenerator is identical to what would be obtained were it replaced by a simple receiver. The dimensions, however, of a simple receiver having a storage capacity equal to that of a regenerator are enormously greater than those of the regenerator; an 8-ft. by 40-ft. Rateau regenerator having as great as storage capacity as a receiver 50 ft. in diameter by 100 ft. long.

TURBINES

Steam turbines have been in the process of evolution for many years, and their chief characteristics are at present well known.

The two types of turbine in extensive use are known as action and re-action machines. To the action type belong the Curtis, De Laval and Rateau machines. The re-action type is represented by the Parsons turbine. In an action type machine the pressure drop ocurs principally in the stationary nozzles, while in the re-action machine a uniform pressure drop occurs in each row of stationary and rotary buckets; consequently, in the re-action type of machine steam leaks around both stationary and rotary blades, thus necessitating that the running clearance between stationary and rotary elements be reduced to the minimum possible value, from which reduction in clearance arises the greatest source of trouble to turbines of this sort; *i. e.,* stripping blades from their stationary and rotary elements.

Stripping of the blades may sometimes be the result of improper fastening of the buckets to the rotor drum. Obviously, the larger the number of rotary buckets, the greater becomes the danger of stripping; first, because each additional blade is an additional possible cause of trouble; and second, because the larger the number of blades, the more restricted the turbine designer is in his method of attachment, owing to the space available and to the permissible cost of construction.

The successful operation of this type of turbine has always depended on most accurate workmanship, together with extreme care in assembling, and thoroughly reliable means to prevent foreign matter being carried by the steam into the turbine.

The close clearance necessary in these machines, to show good steam economies, is frequently sacrificed in order to obtain greater reliability of operation.

Particular care is also required in starting the larger machines of this type, as they must be brought to a uniform temperature, corresponding nearly to the temperature at which the machine is to work before starting, this being necessary in order to allow the various parts to reach their working temperatures and their corresponding heat expansions.

The importance of this feature is readily seen from the fact that the expansion of the rotor when heated from the temperature of the atmosphere up to that of the working steam often exceeds the clearance between rotor and stator. The process of warming up such a machine is a slow one, because, as steam is first admitted, the upper portions of casing and rotor are heated first, causing them to expand; the lower portions, not expanding so much, give a slight curve to both casing and rotor. This disposition for the central portion of the turbine to rise is further augmented by the resistance of the lower portion of the turbine casing to slide lengthwise of the sub-base as it is expanded by increasing temperature.

The significance of these features would not appear if it were not for the close running clearance. An action type of machine, on the contrary, having large running clearances, can with safety be brought up to speed and full load, when cold, in two or three minutes' time.

In the action type of machine the moving element has no appreciable pressure drop from entering to leaving side of its buckets, and therefore no disposition for steam to leak around the buckets in preference to passing through them, consequently a large clearance is permissible round the rotary buckets. Furthermore, the rotary buckets are carried by wheels mounted on a shaft and between contiguous wheel elements the stationary diaphragm containing the expanding nozzles can be carried down to the shaft, between which and the shaft is a running clearance of very much less diameter than that necessitated by the re-action type of machine.

In the opinion of the writer, the re-action machine is confronted with a serious dilemma; a small clearance is required for economy, but involves great risk of accident.

Turbines, in common with all engines, are subject to deterioration with service. The actions tending to lower their steam economy are:

First—A gradual increase in the quantity of steam leaking through clearance spaces, which by-pass the active portion of the turbine; and

Second—The wearing of the buckets and guide veins, distorting them from their proper shape, thus lowering their mechanical efficiency.

The losses coming under the first case are of very little significance in the action turbine, because in such a machine the diameter of the clearance space is small, usually that of the tur-

bine shaft; but in the re-action type of machine the diameter of the clearance space is large and equal to that at the buckets, giving a leakage area much larger than that of the action machine. The clearance is increased with use of the machine, by the wear from steam passing at high velocity, together with the entrained water and particles of dirt.

On both action and re-action machines the buckets are subject to wear, the extent of which depends upon the relative velocity of steam passing over the bucket, the maximum value of which varies inversely as the square root of the number of pressure stages. In the re-action type of machine the wearing of buckets is largely a question of design, and is more or less unaffected by the number of stages. In general it seems probable that the re-action type of machine is subject to a much more rapid loss of efficiency than an action machine, when both causes are taken together.

The question of reliability in daily service is of great interest, and, inasmuch as the turbine reliability depends upon its design, it is impractical to discuss one feature without reference to the other.

RELIABILITY OF OPERATION

From a practical point of view, the reliability of operation is often of more concern than the maintenance of high efficiency.

A turbine is subject to few, but very serious, acidents, which may be classified as follows:

First—Contact between stationary and rotary elements;

Second—Stripping of the blades;

Third—An accident arising through an interruption or failure in action of the auxiliaries employed to maintain the turbine in operation.

The rotary element can only come in contact with the stationary element when the clearance space is small, and when such is the case the intervening space can be bridged by an unequal heat expansion, through foreign matter becoming wedged in the opening, or through a slight loosening of any one of the numerous rotary buckets. If contact is once established, the damage is liable to be severe. It has frequently been stated that the clearance is automatically maintained by the wear which it produces. This may have happened in some instances, but usually the cuttings are welded to the rotary element and pile up, increasing the violence of contact until the heat generated results in serious damage. The damage produced in this manner, through contact of the rotary element, is above all else the most frequent trouble encountered in turbine operation, and every effort should be made to so design and manufacture turbines that this source of annoyance is either entirely eliminated or the probability of this kind of trouble reduced to a minimum.

It appears safe to state that a clearance between stator and rotor less than three-thirty-seconds of an inch is absolutely unsafe, and that a clearance of one-eighth of an inch to five-thirty-seconds of an inch is vastly preferable, so long as the resulting steam leakage is not a factor of importance.

In the larger action type of machines, clearances of this magnitude do not result in losses of the magnitude of one per cent.

The buckets may be stripped by contact with the stationary element. An action turbine has a very large clearance around its buckets (one-quarter of an inch or more) and therefore is practically free from damage of this character. In this type of turbine the minimum clearance occurs between the pressure diaphragm and shaft. When contact occurs between shaft and diaphragm, the resulting damage is generally a warped shaft, caused by a spot on the shaft becoming overheated and, through its expansion, permanently warping the shaft out of line.

An interesting phenomemon is illustrated when shafts come in contact with diaphragms. No matter how perfectly the rotary elements may be balanced, it is impossible to have an exact coincidence between the geometric centre of the shaft and the mass axis of the rotary element. When the machine is running at full speed it rotates as nearly about its mass axis as possible throwing the shaft slightly eccentric, and when contact is established it occurs first at that portion of the shaft surface furthest from its axis of rotation; consequently there is always one spot in the shaft which touches the stationary element first and localizes the heating to a small section of the shaft periphery. The heating of the shaft at this spot expands it, thus lengthening one side of the shaft more than the other, causing it to warp slightly out of true, pushing the spot which has been heated by contact still further away from the axis of rotation and increasing the violence of contact.

This danger can be largely—or entirely—overcome by presenting to the shaft but a very small metallic surface, or by facing the diaphragms with carbon blocks, which, through their nature, are incapable of presenting sufficient resistance to cause a violent heating.

The preservation of a proper clearance between rotor and stator, as between one type of machine and another, is a question of its design and construction. The machine that is so constructed that, when nearly assembled, the running clearance may be inspected, has a great advantage over the machine which must be put together piece by piece.

The vertical machine is at a disadvantage in this respect on account of the necessity of assembling it piece by piece, threading over the shaft successively diaphragms and wheels, thus placing on the erector of the machine a great responsibility and difficulty in maintaining the clearance; for after a wheel and diaphragm have been placed, it is difficult to inspect the clearance. A horizontal machine, on the other hand, eliminates this difficulty almost entirely, for in such machines it is possible to split the machine through its horizontal centre and assemble in position each half, then inspect the clearance between each partially assembled half and the assembled rotor.

The turbine auxiliaries are the pumps for lubrication and for supplying the fluid pressure to step bearings. Frequently, also, the governor mechanism includes an auxiliary as a connecting link between the fly ball governor and the control valves. Any one of these may cause trouble to the turbine, since its operation is dependent upon them, and their failure results in the failure of the whole turbine.

All of these auxiliaries appear unnecessary, and it would seem that they were introduced as a means of patching up features which might better have been omitted.

Bearings have been lubricated by oil rings for many years, and the bearing of a turbine may be lubricated by an oil ring with the same ease as the bearing of a 1-h.p. motor.

An auxiliary, to maintain in action a step bearing, has been made more reliable by the installation of two pumps and a hydraulic accumulator, so that any two of these elements may fail, leaving one in operation. This seems a somewhat elaborate method of increasing the reliability of an essentially simple machine, and perhaps the easiest way to obtain the desired results would consist in omitting entirely the step bearing by placing the turbine in a horizontal position.

A forced feed bearing lubrication is thought necessary in the re-action type of turbine, because in such machines, having as necessity a close running clearance, the bearings must also be given a close running clearance, which is too small to permit oil to enter the rubbing surfaces unless its entrance is forced. In a vertical type machine, oil ring bearings are of course an impossibility.

As an example of what can be done in simplfying turbines, Figs. 3 and 4 illustrate a Rateau-Smoot turbine. In this machine, the bearings are babbitt-lined, self-aligning, water-cooled and lubricated with oil rings. The complete journal bushing can be removed without disturbing any other portion of the turbine except the bearing which is to be opened.

Between the shaft and diaphragms the least clearance is three-thirty-seconds of an inch, and between buckets and casing the minimum clearance is one-quarter of an inch. The wheels are of the type illustrated in Fig. 11. The buckets are illustrated in Fig. 10, and are held astride of the wheel periphery by transverse rivets, this eliminating all metal at the wheel periphery not absolutely required for the bucket attachment. The strength of these wheels, together with their buckets, is sufficient to allow the machine to be run at double its normal speed (the stresses at double speed are four times those under normal conditions), without permanent deformation of wheels or buckets, or causing an alteration in the balance of the machine.

The governor of this machine is mounted directly on the turbine shaft, and the motion from the fly balls is transmitted by a solid steel link to the steam admission valve, which is of the well-known double poppet balanced type, and controls the machine by throttling the steam, thus varying gradually the amount of steam admitted to the turbine.

The writer thinks that this is a superior method of governing a turbine than by means of a series of nozzles which are operated either wide open or closed, for it frequently happens that the load which the turbine is driving is represented by a certain number of nozzles wide open, plus an additional amount less than one complete nozzle opening, consequently it is impossible to maintain the turbine at a constant speed, for a slight increase of speed is necessary to open wide the additional nozzle, and a slight decrease necessary to cause its shutting, thus compelling the turbine to run between these two limits—*i. e.*, the speed sufficient to open the valve and a speed sufficient to close it. This is particularly annoying when turbines are operating in parallel with other turbines having a similar control, or with reciprocating engines, for it is possible that the disposition for slight speed oscillation may fall in step with those of other turbines or engines, and cause fairly pronounced oscillations in the entire system. Instances of this kind have been noticed. With a straight throttling governor, on the other hand, the variation in the quantity of steam admitted to the turbine is absolutely gradual, and a perfect balance can be maintained between the load and the quantity of steam applied to the turbine.

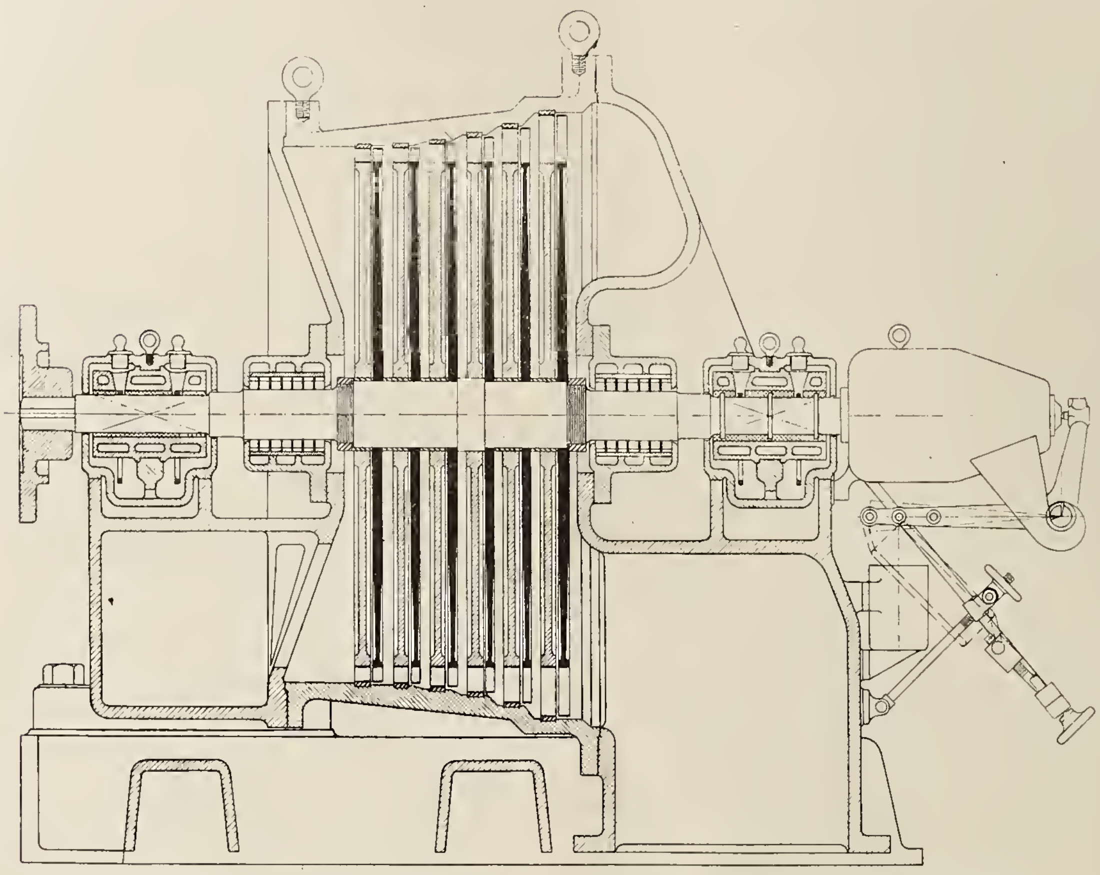

Fig. 3.—CROSS-SECTION OF RATEAU-SMOOT 750-KW. LOW-PRESSURE TURBINE.

The machine illustrated is in operation at the Vandergrift plant of the American Sheet and Tin Plate Company, and is running in an extension of the rolling-mill buildings, where the air is full of metallic dust and scale from the mills.

The speed regulation is such that at a given load the variation from time to time is less than 0.25 per cent. The variation between no load and full load can be adjusted to any figure desired. As at present operating, the machine runs at 1500 rev. per min. at full load and 1500 rev. per min. at no load.

One man, by exerting his strength on the governor mechanism can alter the speed 1.5 per cent., but is unable to cause a sustained oscillation.

The cut referred to above, Fig. 3, includes the entire turbine, and the only auxiliary not shown is the condensing apparatus.

Governing mechanisms, in which the fly balls do not control directly the admission valve, but do so through the agency of an intermediate motor or other mechanical device, whose source of energy is independent of the fly balls, are always equipped with a speed-limit device, and advisedly so, because of the intermediate motor, which is a break in the connecting link between fly balls and control valves. The presence of this intermediate motor is required by the large amount of energy needed to operate unbalanced valves on the one hand, and the small amount of energy available in the fly ball governor on the other hand; hence the motor to supply the deficiency in energy of the fly balls and to overcome the heavy unbalance of the valves.

This type of governor appears a very complicated mechanism, one part of which is required to overcome the inherent difficulties presented by the other part. A more practical method is to put the control valves approximately in balance and to connect them by solid links to the governor fly balls, which may be given sufficient energy to operate the valves within the speed regulation desired.

COMPARISON OF CURTIS AND RATEAU TURBINES

The types of action turbine which have been most fully developed and which represent the most promising features, both in economy and reliability of operation, are the types known as "Curtis" and "Rateau." Both of these types lend themselves to the construction of units in sizes up to the largest single power-producing unit yet conceived.

Aside from very important consideration of general arrangement, the essential difference between the Curtis and Rateau machines lies in the following:

In the Rateau machine steam is expanded successively in a series of nozzles playing on moving buckets which absorb entirely the tangential component of the exit velocity from the nozzles. After leaving the row of

moving buckets, the steam, which has been reduced to only sufficient velocity for its flow through the turbine, enters another row of nozzles through which there is a pressure drop creating a second velocity, which is in turn absorbed by a second row of moving buckets, and so on to the exhaust end of the turbine.

Fig. 4.—VANDERGRIFT-RATEAU-SMOOT LOW-PRESSURE TURBO-DYNAMO, 750 KW., DIRECT CURRENT, 250 VOLTS, 1500 REV. PER MIN.

In the Curtis machine the pressure drop, which in the Rateau type occurs through two nozzles, is lumped into one nozzle, which often is of the converging-diverging type, in order that the exit velocity may exceed the critical velocity for steam.

The steam from this nozzle is then received by a row of moving buckets, the speed of which, however, is insufficient to completely absorb the tangential component of the original velocity, and therefor the velocity of the steam leaving the first row of buckets represents a considerable amount of energy which is utilized in a second row of buckets by passing it through stationary guide veins so arranged as to reverse its tangential component, directing the steam anew upon the second row of buckets.

At present a Rateau low-pressure turbine of large size would have for high vacuum eight successive steam nozzles and eight successive rows of moving buckets. The corresponding Curtis machine would probably have four successive steam nozzles, each playing on two rows of moving buckets, making a total of eight rows of moving buckets. Under these conditions, with an admission pressure equal to atmosphere and an exhaust presure of 27.5 in. on a 30-in. barometer, the steam velocity leaving the Rateau nozzles would be approximately 330 metres per second, and the velocity leaving the Curtis nozzles would be approximately 456 metres, at which condition it enters the first row of buckets. In the Rateau machine this velocity is reduced to just enough for the steam to flow into the next succeeding nozzles, while in the Curtis machine such a reduction is impossible and the large exit velocity from the first row of buckets passes through guide blades, which, without a change of pressure, reverse the steam flow and permit the velocity remaining to be absorbed in a second row of buckets.

It is of interest to note that experiments have thoroughly established the fact that the loss of energy due to friction and eddy currents in a well-designed steam nozzle, in which velocity is created by a reduction of pressure, does not exceed 5 per cent., and in nozzles of large sectional area comes down to 2 per cent., while the energy loss when steam at high velocity is caused to move in a curved channel—as in the rotary buckets and stationary guide blades of the Curtis machine, which are equivalent to buckets—runs all the way from 15 to 30 per cent., dependent upon the design, construction, size, *et cetera*, of the buckets.

For equivalent pressure drops, the Rateau type of machine has two nozzles, in which the loss is small, and two rows of moving buckets, in which the loss is large. The equivalent Curtis element representing an equal pressure drop has one nozzle, in which the loss is small, followed by two rows of moving buckets and one row of stationary guides, three in all, for which the loss is high. Thus, between the Rateau machine and the Curtis machine, the substitution of stationary guide blades in the Curtis machine for nozzles in the Rateau machine introduces in the Curtis machine an element of high energy loss, which is represented in the Rateau machine by an element of low energy loss.

Figs. 5 and 6 show, respectively, the corresponding elements of Rateau and Curtis turbines. The elements being placed one over the other, show immediately that in the Curtis machine deflecting guide blades, constructed like buckets, having high energy losses, are used where in the Rateau machine there is an expanding nozzle of low energy loss.

This same feature has been very clearly shown by Professor Rateau in his paper at the St. Louis convention, during the World's Fair, in which he demonstrated irrefutably that the multi-velocity stage turbine was at a marked disadvantage in comparison with the multicellular type, in which but one nozzle and one bucket wheel are employed to a pressure stage.

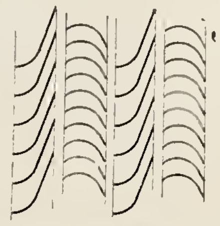

Fig. 5.—RATEAU BUCKETS AND NOZZLES.

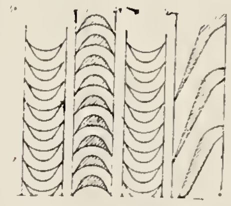

Fig. 6.—CURTIS BUCKETS AND NOZZLES.

Professor Rateau, in his paper, further showed that the maximum possible obtainable efficiency with each type of turbine differed some 20 per cent. with the bucket construction then in use, and that the difference could not be overcome by any feature of bucket construction or design, since whatever is obtainable in one type of machine in the way of reducing losses in buckets is also possible in the other type of machine, the Curtis type having, however, always the additional loss represented by the stationary guide blades constructed like buckets and having losses equivalent to those occurring in a bucket, while in the Rateau type of machine the corresponding element is an expanding nozzle in which the losses are very small. In addition to this, the losses of energy due to shock are greater in the first row of buckets on the Curtis machine, because the entering steam has some 40 per cent. greater velocity than in the Rateau type. These differences can not be overcome and will always prove to the disadvantage of the Curtis turbine.

TURBINE BUCKETS

Fig. 7 represents a row of buckets, the centre portion of which has been increased to give between adjacent buckets approximately a uniform width of steam channel. The angles of entrance for steam at full load and light load are shown by arrows in the cut. Fig. 8 shows the type of buckets employed in the Rateau-Smoot turbine, with the

angles of steam entrance for full and light load also indicated.

These figures show that it is a mistake to increase the thickness of a bucket toward the centre, as at light loads the entering steam abruptly

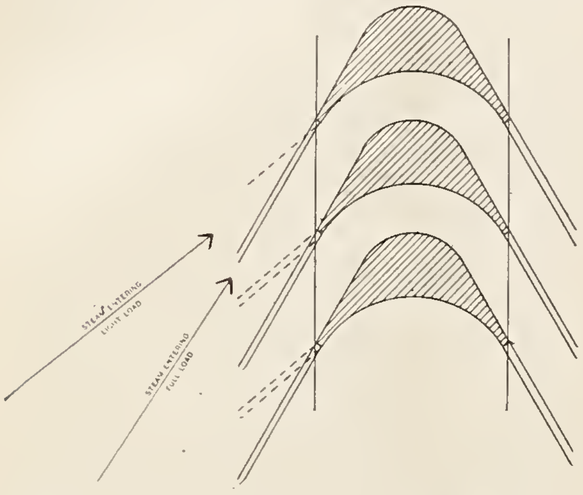

Fig. 7—STEAM FLOW AT FULL LOAD AND STEAM AT LIGHT LOAD IN CRESCENT-SHAPED BUCKETS AND IN BUCKETS OF UNIFORM THICKNESS.

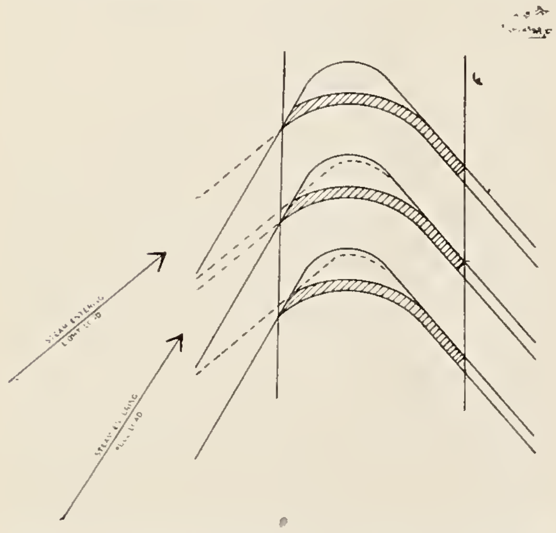

Fig. 8—STEAM FLOW AT FULL LOAD AND STEAM AT LIGHT LOAD IN CRESCENT-SHAPED BUCKETS AND IN BUCKETS OF UNIFORM THICKNESS.

strikes the rear of the bucket. The loss resulting is doubled. First, there occurs the loss due to the steam shock itself; and second, the loss due to the fact that the reaction from this shock is tending to drive the turbine backward and not forward.

The writer is quite unable to see any advantage in a bucket which is thicker in the middle, having a crescent section. As a matter of resisting the steam wear, it should be noted that the edges of all buckets, whether of crescent section or otherwise, are the portions principally subject to the steam erosion and are of necessity made thin in order to reduce the steam friction of the jet entering the bucket wheel. When these thin edges are worn the bucket has lost its proper section and becomes highly inefficient, for the crescent section equally as well as for a section of uniform thickness. In addition to this time, which is negative in its character, a crescent section bucket presents the disadvantage above noted of increased losses on the light loads; but still more serious from the designer's point of view, it greatly increases the weight of metal in the bucket.

At ordinary bucket speeds for the multi-stage type of turbine, the centrifugal force per pound of bucket weight amount to from 1000 to 2000 lb., and therefore each additional pound of material over that absolutely necessary adds to the wheel an enormous disruptive effort.

The function of the wheel is primarily to hold the buckets, and if the the weight of the buckets is doubled the weight of the wheel itself must be doubled in order to hold the buckets securely in position.

The limiting strain in the wheel is its elastic limit and not the ultimate strength of the material employed, for if once the elastic limit of a wheel has been exceeded, it is stretched out of its original shape and the running balance destroyed, causing the turbine to become inoperative through the violence of vibration ensuing. With equal weight, the strongest wheel is the one which has the lightest periphery, for it is the weight of the periphery which produces the strain.

Buckets which are held in position by means of a dovetailed fit are objectionable because of the large amount of weight entailed by the dovetail construction. On the other hand, the bucket which is held astride of the wheel and riveted through by rivets parallel to the shaft has maximum lightness for the strength requisite to hold the buckets in place. We consider this latter construction vastly superior to any other yet produced, for the reasons heretofore enumerated.

Fig. 9 shows a typical dovetailed method of mounting buckets on their wheel, and Fig. 10 shows the type of mounting adopted in the Rateau-Smoot turbine.

It should be adopted that much less metal is required at the wheel rim in the Rateau-Smoot turbine than is required by the dovetail construction. This metal is entirely unable to hold itself against the centrifugal force produced by its rotation and therefore must be carried by metal provided at the center of the disc, a heavy section being a source of weakness rather than one of strength.

The cross-section of the Rateau-Smoot bucket and wheel is taken from a 2000-kw., 1500-r.p.m. low-pressure turbine and can be driven at 3000 r.p.m. without producing a strain in buckets or wheels exceeding the elastic limit of ordinary flanged steel plate.

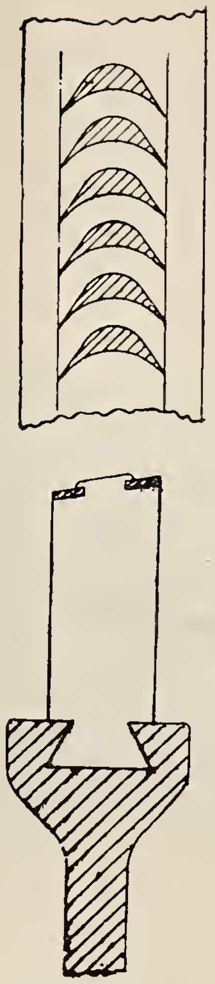

Fig. 9.—DOVETAILED BUCKETS.

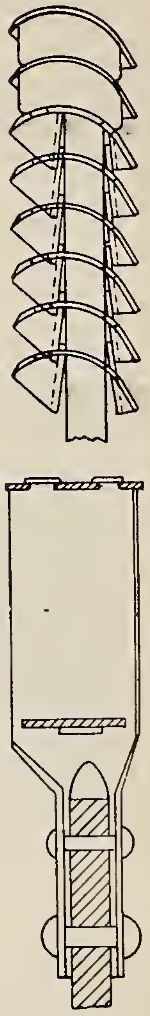

Fig. 10.—BUCKETS HELD ASTRIDE.

BUCKET WHEELS

Since the original single-wheel turbine, running at enormous speeds, invented by De Laval, various analyses have been made of the strains and strengths of discs turning at high speeds. All of these analyses unfortunately contain as prime assumption a practical fallacy. These wheels have been designed for uniform strains in both tangential and radial directions, and the material of the wheel has been treated as if its elastic limit coincided with its ultimate strength, the point of danger being considered as the elastic limit. The result produces a wheel section whose fallacy will be obvious, when it is borne in mind that all metal placed within a radius lettered *B*. Fig. 11 is capable of holding itself and also an additional load, while all metal external to the radius lettered *B* is incapable of holding itself against centrifugal force, consequently it is simply necessary to add sufficient metal within this radius to hold together the entire wheel. When a wheel has been designed for uniform radial and tangential stresses, the section is that shown by Fig. 12, in which it will be noted more metal is added outside of the critical radius than for the wheel illustrated in Fig. 11. The assumption of equal radial and tangential stresses as the basis for wheel design leads to an irrational conclusion; either radial or

tangential stress is sufficient to hold the wheel together, as all material suitable for the construction of a turbine wheel possesses in a high degree the property of stretching beyond the elastic limit, and when tangential stresses exceed the elastic limit and radial stresses fall under the elastic limit, an infinitesimal stretch in a tangential direction will allow a sufficient elongation radially for the radial stresses to carry their proper share of the load.

While it is true that a wheel is unsatisfactory if both tangential and radial stresses exceed the elastic limit, it should also be borne in mind that either one can hold in position the wheel, regardless of what happens to the other.

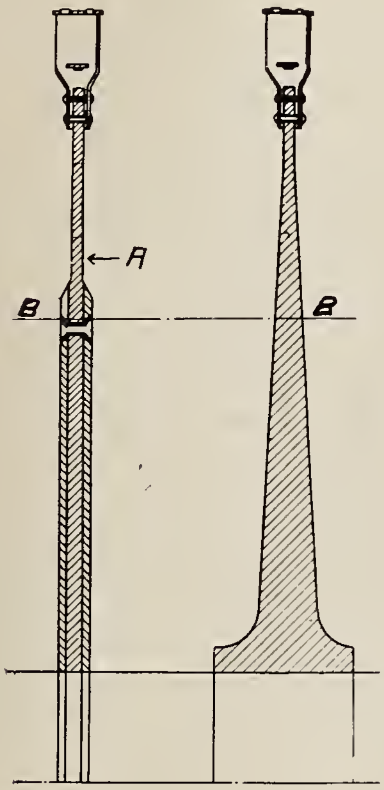

Fig. 11 Fig. 12

For example, in the wheel illustrated by Fig. 11, the maximum stress has been taken at 8000 lb. per square inch, the material being ordinary flange steel. At the position lettered *A*, the tangential stresses may considerably exceed the elastic limit. The radial stresses, however, are much under the elastic limit, and when under test, prior to assembling on the shaft, the wheel has been brought to double its normal speed, a minute tangential stretch of the wheel allows the radial stresses to reach a sufficient value to hold the outer periphery to the heavier central portion, the permanent stretching occurring tangentially, but not radially, thus allowing the radial stresses to assume a value sufficient to hold the wheel together.

TURBINE SHAFTS

Starting from a bucket of known weight, a wheel can be calculated strong enough to hold the buckets in place. The heavier the bucket, in equal proportion the heavier the wheel, consequently heavy buckets produce heavy wheels. Heavy wheels reduce the critical speed of the shaft, unless the shaft is also made heavier to offset the effect of the increased weight placed upon it. It is objectionable to use a large shaft, for two reasons: First, because it increases the peripheral speed of rubbing surfaces in the bearing, making them more difficult to keep cool; and second, because it increases the diameter of the clearance space between shaft and pressure diaphragms, adding to the steam leakage.

Various attempts have been made to operate turbines in which the normal running speed was greater than the critical speed (the critical speed of a shaft is the speed corresponding to the number of vibrations which the shaft, together with its carried weight, will vibrate, and when given in revolutions per minute is the oscillations per minute which the shaft can sustain when once started oscillating).

The calculation of critical speeds can be carried out by the process of graphical integration, and highly accurate results obtained, no matter how complex the distribution of load upon the shaft may be or how widely varying may be the shaft diameter.

The execution of such a calculation, however, is a cumbersome matter, and when the critical speeds of a series of different shafts have been determined in this manner, the corresponding constants g in the following formula for critical speeds.

Critical speed (rev. per min.) =

$$g \times 10^6 \times \frac{D}{L\sqrt{L \times W}}$$

are determined for all shafts whose essential characteristics are similar to those whose complete analysis has has been carried through.

When sufficient experience has been gathered to determine for a given shaft the value of this constant, the critical speed of the shaft may be taken from a logarithmic plot, as shown in Fig. 13, which gives the critical speeds for the value of the constant g equal to 1.05, the value most frequently encountered in turbines of the multicellular type. For turbines whose shaft construction entails a different value of g, the cor-

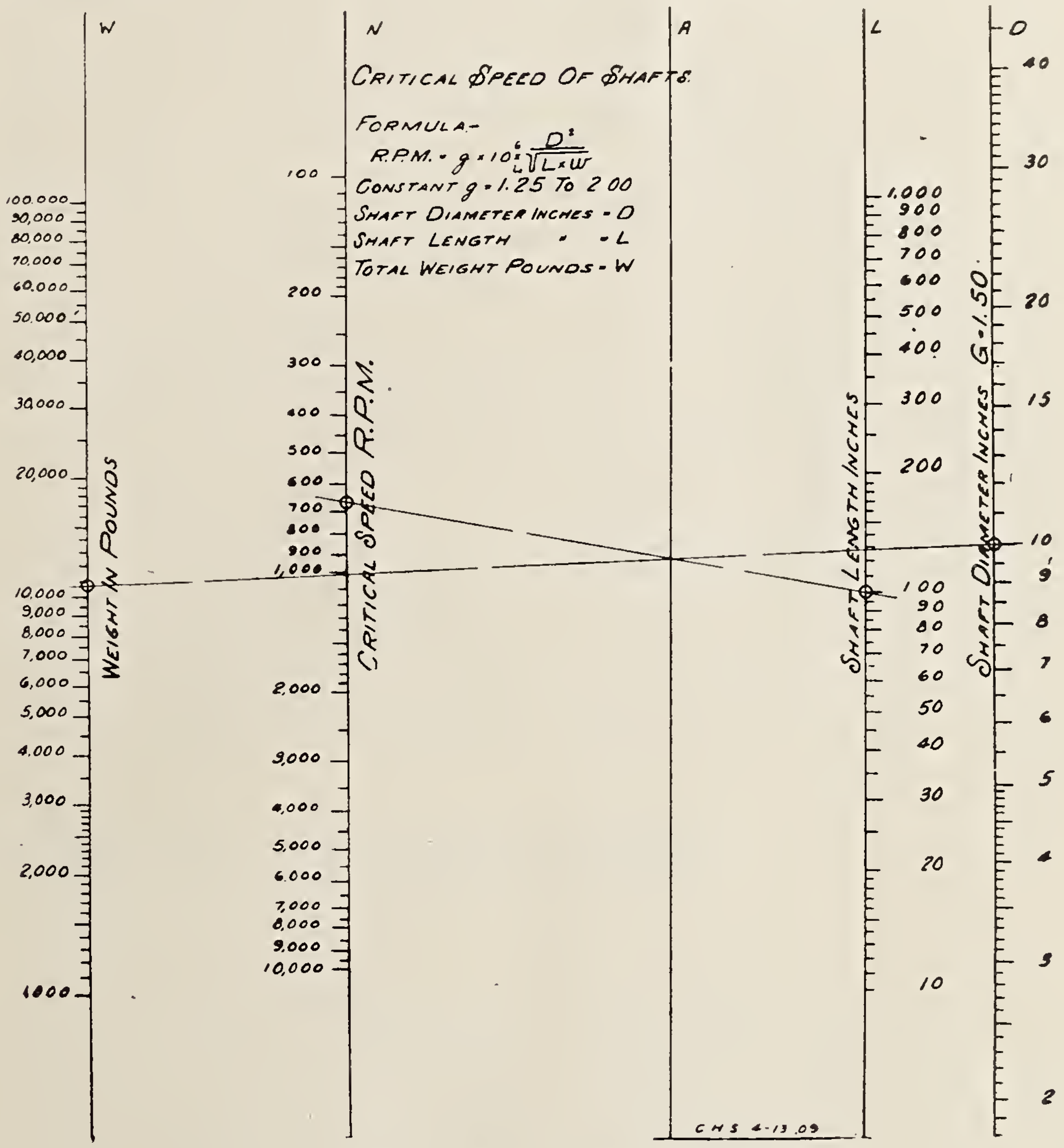

Fig. 13—CRITICAL SPEED OF SHAFTS

responding critical speed may be directly deduced from that given by the logarithmic plot above referred to.

VIBRATIONS

A turbine may vibrate objectionably or destructively, depending upon the amplitude of the vibrations. The causes of the vibrations may be found either in a shaft whose critical speed is under the running speed, or in wheels which have strains both radial and tangential near the elastic limit, thus causing a slow and continual deformation of the wheel and consequent shifting of its mass axis. From the dynamo end, vibrations can also be set up if the windings are insecurely held in position and gradually shift their position.

A properly designed turbine and dynamo, when once placed in balance so that the unit runs quietly, should never show a tendency for greater vibration; and, when such is the case, the design is at fault, for the weights carried on the shafts must shift in order to throw the machine out of balance.

Incidentally, this would seem to condemn a turbine and dynamo running on three bearings, for in such a machine any slight disposition toward vibration in turbine or dynamo will be transmitted through the solid shaft and set up vibrations in the other unit, thus causing the turbine to vibrate and its shaft to tremble when the turbine itself is not at fault, but the dynamo is out of balance.

We consider the three-bearing machine questionable for this specific reason, in addition to the well-known difficulty of maintaining in perfect alignment three bearings. Another serious objection to a three-bearing machine is that the shaft may pound on the central bearing, for the unit endeavors to run as a two-bearing machine running free of the central bearing and oscillating by the clearance given that bearing, thus placing on the central bearing the duty of restricting oscillations and limiting their amplitude by absorbing the blow struck by the shaft for each oscillation.

In vertical machines this sometimes results in very serious damage to the fastenings of the central bearing, for under these conditions it is subjected to enormous lateral strains, capable in some instances of shearing loose the attachment of the central bearing to the supporting framework. We consider it vastly better, although somewhat more expensive, to allow a bearing at either end of turbine and dynamo shaft, and to insulate against transmitted vibrations from one to the other by entirely breaking the continuity of the shaft, in so far as its transverse strength is concerned, placing between the two central bearings a non-rigid coupling, which will allow one shaft to bend without transmitting a bending movement to the other shaft.

OIL RING BEARINGS

The writer had the opportunity of investigating the action of oil in bearings running at high speed, and ran a 5-in. by 13-in. bearing at full speed (1500 rev. per min.) with normal load with the top cap removed.

The bearing in which the experiment was made was provided with the usual oil grooves and lubricated by rings having a positive pumping action, supplying oil from the oil reservoir to the journal. At half speed and above, oil, instead of being carried into the journal through the oil grooves, squirted upward from the grooves against the direction of rotation, each groove throwing a stream of oil 0.25 in. in diameter several feet into the air, showing that the grooves simply provided vents for the back flow of the oil, which would otherwise have been carried into the journal, through its adhesion to the shaft, and indicating the truth of a theory which we have all held, but with considerable doubt, that a high-speed journal floated on an oil film.

In this paper I have endeavored to show that steam turbines are in no way dependent on accurate workmanship for their reliability, and that simplicity and reliability will always go together in their construction.

I have also wished to express the idea that high efficiencies can be obtained without endangering the reliability of the turbine.

Low cost of construction, absolute reliability, maintenance reduced to a minimum, and high efficiency may assure to the turbine a future of increasing importance.

Furthermore, I strongly suggest that owners of non-condensing plants consider the opportunity of utilizing the exhaust of their reciprocating engines in low-pressure steam turbines, and thereby adopt a method of rejuvenating their plants by one of the most efficient methods of developing power from steam.

Electrostatic Instruments

H. D. RICHARDSON

Electrostatic instruments are used as ground detectors and voltmeters.* They do not depend for their action upon a flow of current through a winding, but upon the principle that two bodies or plates oppositely charged will tend to attract one another. A plate, usually of aluminum, is mounted on a shaft and suspended between stationary plates. In many ground detectors the moving vane is connected to the ground and the fixed plates to the line wires. One prominent manufacturer, however, connects one set of fixed plates to the ground, another set to the line wires, thus leaving the moving aluminum vane to carry an induced electrostatic charge. This construction reduces the chance for a short circuit in the instrument due to an abnormal rise of the tested voltage.

The indicating needle is carried by the moving vane and its position depends upon the amount of ground, or what is the same thing, upon the force of the attracting charges and the opposing torque, which is secured by a control spring or the pull of gravity upon counterweights. The attraction between the plates varies as the square of the voltage, hence the scale is very open at the upper end.

These instruments consume little energy and are unaffected by magnetic fields, and can be connected directly to high-potential circuits.

Since they are essentially condensers and their action depends upon capacity, they have a tendency to be affected by variation of the frequency or by wave form. This is easily shown by calibrating the instrument on a sine wave and then checking it on a wave form having higher harmonics.

One of the principal difficulties of design is that the actuating forces are very small and friction is therefore apt to produce errors. In order to reduce the friction factor the torque must be increased, and it is therefore necesary to make the distance between the fixed and moving plates a minimum. This may introduce another troublesome feature, that of sparking or brush discharge between plates. If for any reason there should occur an excessive rise of potential, high resistance, usually in the form of graphitized carbon rods, is placed in series with the instrument to prevent excessive flow of current, in case an

*Continued from March Issue.

internal short circuit should occur. Since these instruments depend upon electrostatic charges for their action, they are, of course, very susceptible to stray electrostatic fields.

The low torque and the effect of frequency and wave form variation render this type of instrument less reliable as a voltmeter than some other types. When used on circuits above 20,000 volts it is not connected directly to the circuit, but is used in connection with condenser multipliers. The use of condenser multipliers may be avoided by submerging the plates and vanes in oil.

D'ARSONVAL INSTRUMENTS.

D'Arsonval instruments are used on direct-current circuits only and are limited to ammeters and voltmeters. The Weston D'Arsonval instrument, the original patents of which have recently expired, is representative of this type and has come to be recognized as the standard for direct-current work. Considerable credit is due the manufacturer of this instrument, for without a doubt the present stage of the art of instrument design has been largely determined by the efficiency of this type.

The principle of action is that of a coil of fine copper wire wound on a small aluminum holder and moving in a uniform magnetic field. A permanent magnet with annular pole pieces maintains the magnetic field. The moving coil encircles a stationary soft-iron core, thus concentrating the field upon which the current in the moving coil receives its turning movement. The angle turned through is proportional to the flow of the current. The counter torque is secured by a spiral control spring, which exerts a force proportional to the angular position of the coil; the result is a uniformly divided scale.

The field of the permanent magnet is relatively strong, about 700 lines per square centimeter, hence only a few ampere turns are required on the moving coil. This means small energy, consumption, strong torque, light-weight moving element and good damping qualities, constituting an exceedingly efficient combination. The voltage drop for the ammeter approximates 0.03 to 0.06 volt, about one-tenth that of the hot-wire ammeter, thus making it a successful instrument for use with a shunt. The resistance of the moving coil of the voltmeter is 10 to 20 ohms, hence the copper temperature co-efficient is easily eliminated by connecting in series a resistance of negative or zero temperature co-efficient. The temperature co-efficient of a well-designed instrument should not exceed 0.01 per cent. per degree centigrade.

There are two sources of error which may prove exceedingly objectionable—a change in the strength of the control spring or a change in the strength of the permanent magnet. The spring may not have been properly aged, and continued use under tension, accompanied by temperature variations, may cause it to take a "set," thus producing inaccurate indications of the indicating needle. If the needle does not return to the exact zero mark it shows that either the needle is bent or the control spring has changed its strength.

In the D'Arsonval instrument the control spring also serves to convey the current to the moving coil. In an ammeter this is a very important consideration in the design, because the temperature co-efficient of the control spring varies from 0.1 to 0.4 per degree Centigrade, depending upon the material used, while the resistance may vary from 0.1 to 0.5 ohms, depending upon the grade of instrument. It is, therefore, necessary to employ in series with the armature as much zero or negative temperature co-efficient wire as possible.

The present methods of producing, hardening and magnetizing permanent magnets are so far advanced and the design of the magnetic circuit is such that scarcely any trouble will be experienced due to a change in the strength of the magnet. The permanence of life of a magnet depends upon making the reluctance a minimum. The length of steel and iron must be very much greater than the air gap and the cross section of the air gap larger than the average cross section of the steel.

The longer the air gap and the smaller its cross-sectional area the greater the percentage leakage of flux, hence the more susceptible will the instrument be to stray magnetic fields from external sources.

Since this class of instruments operates upon magnetic principles, it is apt to be very susceptible to stray fields unless properly shielded. In an unshielded permanent magnet instrument of moderate air gap the earth's field alone will produce an error of one per cent. In order to protect switchboard instruments of this type the operating parts are mounted in an iron case.

The effect of stray fields is also eliminated by using two magnets and arranging their four poles astatically, *i. e.,* so that if a stray magnetic field increases the strength of one set of pole pieces it will produce a corresponding decrease of intensity in the other set of pole pieces. This arrangement forms two magnetic fields in opposite directions in which the armature moves. The armature winding consists of two coils in series, one wound in one direction, the other in the opposite direction and so mounted that one coil is acted upon by only one of the magnetic fields and the other coil by the other field. The effect of a stray field from some external source will have a positive effect on one half of the armature and an equal negative effect on the other half, so that the error due to the stray field is entirely eliminated. The armature coils are well protected, being mounted between two thin sheets of aluminum. The movement of the armature causes the generation of eddy currents in these aluminum disks, thereby ensuring excellent dead-beat qualities and a light-weight armature. The four magnet poles produce a very high torque without increased energy consumption.

The method of control in the astatic instrument is equally unique and interesting. Neither control springs or counterweights are used. The control is entirely magnetic. On the shaft of the moving element are mounted two small rectangular pieces of soft iron, one on one side of the armature, the other on the opposite side of the armature. These pieces of iron are located on the shaft so that they take advantage of a magnetic field set up by the pole pieces, which is parallel to the armature and at right angles to the field in which the armature moves and receives its turning moment. Like a compass needle, these rectangular pieces of iron try to turn to a position so as to be intercepted by a minimum number of lines of force. With no current flowing in the armature coils and by turning these iron control pieces on the shaft to this position, the zero mark for the needle is located. The full scale mark is determined by adjusting the amount of resistance in series with the armature when current is flowing in its winding.

The torque of the instrument is proportional to the current flowing in the armature, while the counter-torque exerted on the control pieces is proportional to their angular position, the result is an evenly divided scale.

By turning the iron control pieces on the shaft to the proper position the zero mark may be located at any desired point on the scale, thus permitting the instrument to be used when the direction of current flow is reversed, as is the case in charging and discharging storage batteries.

These astatic instruments are still further protected from stray fields by mounting them in cast-iron cases. It will be seen that this particular type of D'Arsonval instrument is very desirable for switchboard use, especially

where the bus bars carry heavy currents.

DYNAMOMETER INSTRUMENTS.

The dynamometer type of instrument is constructed from two coils of wire, one of which is fixed and the other movable; the fixed coil is usually made to enclose the moving coil. No permanent magnet or iron is used to set up a field, and the field which is developed is comparatively weak, not more than one-fifth and seldom more than one-tenth that of a permanent magnet type of instrument. This means a large number of ampere turns is required on the moving and fixed coils in order to secure the necessary torque. Although the absence of iron results in a weak field, it has the advantage that on alternating currents the effect of frequency and wave-form variations is very slight. The moving coil is heavier than that of the D'Arsonval type, hence the temperature coefficient is apt to be relatively higher than in a permanent magnet instrument or an instrument naturally possessing higher torque.

Dynamometer instruments can be used on either direct or alternating current. When used on alternating current the self-induction of the circuits comprising the fixed and moving coils should be kept a minimum; 0.025 henry is a fair value.

One of the chief drawbacks of this type of instrument is its relatively weak torque, hence it is apt to be affected by stray magnetic fields; the earth's field alone may cause an error of 2 per cent. on the lower half of the scale. Stray field effects may, however, be efficiently guarded against by properly shielding the instrument with an internal magnetic shield or by a cast-iron cover or by a combination of both.

The indicating wattmeter is usually the representative of the dynamometer type instrument, yet voltmeters, polyphase indicating wattmeters, power-factor indicators and frequency indicators are included in this classification. In the wattemeter and power-factor indicator the fixed coil carries current proportional to the line current, while the moving coil or coils carry current proportional to the voltage. The frequency indicator and voltmeter are both connected across the line and do not depend for their action upon the line current. The polyphase wattmeter is essentially two single-phase wattmeters combined under one cover, actuating one indicating needle. There are two fixed current coils and two movable potential coils, the moving coils being mounted on a single shaft which actuates the indicating needle. The polyphase wattmeter will indicate the true watts of the circuit for either balanced or unbalanced loads and regardless of the nature of the load.

The power-factor indicator posseses either one current coil and two potential coils or two current coils and one potential coil. It is intended only for use on circuits which are approximately balanced. Its accuracy is unaffected by current or voltage variations, but, like the wattmeter, it should be thoroughly shielded.

The frequency indicator as sometimes constructed comprises two fixed fields coils in series with one another and two moving coils. The latter are rigidly mounted together at a definite angle with one another on the same shaft which operates the needle. Changing this angle between the coils alters the scale distribution and destroys the calibration. No control springs are required as the currents in the moving coils set up directive forces, which, with the fixed coils, determine the position of the indicating needle.

One of the moving coils is in series with a very high reactance, while the other moving coil is in series with a non-inductive resistance; these two circuits then being connected in multiple. The field coils and a resistance are in series with this combination. When the frequency is normal the current in both moving coils is the same, thus producing directive forces of equal value determining the location of the needle at the center of the scale. Any change of frequency will affect the intensity of current flow in the inductive circuit, yet the current in the non-inductive circuit remains unaffected. The ratios of these two currents, therefore, determine the indications of the needle.

It will be noted that the inductive and non-inductive circuits are in multiple, hence if the voltage changed the drop across these two internal circuits of the indicator will change the same amount and the ratio of currents is unaltered. This means that the instrument is unaffected by voltage variations. Wave form has but a slight effect on the accuracy; the reactance seems to "screen out" the higher harmonics to a great extent. In the instalation of a frequency indicator care should be exercised to see that the box containing the reactance is mounted in a place not subjected to stray magnetic fields of much strength.

Eddy currents set up in various metallic parts of dynamometer instruments will not prove serious on high power-factors since they are practically 90 degrees out of phase with the currents in the fixed and moving coils. This effect may, however, prove seriouse on low power-factors. The errors may be eliminated by the use of an internal magnetic shield since the stray flux from the coils which causes the eddy currents in intercepted.

ELECTROMAGNETIC INSTRUMENTS.

The use of a permanent magnet makes it possible to secure an instrument of great sensitiveness. In order that an alternating-current instrument be equally as sensitive a strong magnetic field is necessary. This is possible by the use of the electro-magnet, by the magnetization of iron or by induction. The effect of frequency, wave form and inductive load variations made the design a troublesome problem. The methods of overcoming these difficulties have not only been ingenious, but the results very satisfactory. Fully as much credit is due to those who have developed the electromagnetic type of instrument as is due the designers of the D'Arsonval type. At the present time a very large percentage of modern switchboard instruments are of the electromagnetic principle of construction.

The principle is that a piece of iron tends to move to the strongest part of a magnetic field. The iron may also be polarized by induction from a coil of wire, in which case if the iron is free to move it tends to set itself in such a position that it is cut by a minimum number of lines of force.

Many of these instruments can be used with equal satisfaction on both alternating and direct-current circuits, since their principle of action depends upon the magnetization of iron.

When used on direct current the presence of iron is apt to show errors due to the effect of hysteresis. These erors can be reduced to a minimum by designing the instrument so that the greater part of the path for the magnetic flux lies outside the iron. The distance between opposite ends or poles of the iron should be as short as is consistent, in order that the demagnetizating effect of the ends will be a maximum. Working the iron at a low density will also reduce the hysteresis errors.

In order to secure high torque a relatively large volume of iron is required. This means increased weight for the moving element, resulting in increase of friction at the bearings. If the amount of iron is too small the torque is too small and friction errors are apt to be more prominent.

Working the iron at a high density to secure high torque tends to saturate the iron and the resulting torque is closely proportional to the instantaneous values of the current. When the iron is operated at a low density the torque is apt to be low and approxi-

mately proportional to the square of the current.

The magnetizing current is less with a peaked wave than with a sine wave, hence if the instrument is calibrated on a sine wave and then used on a peaked wave the indications will tend to read high.

It is oftentimes said that because the effect of wave form is present variations of frequency will also be noticeable. This does not necessarily follow since frequency errors are due to self-induction and not to the presence of the iron. An instrument calibrated on one wave form will probably be unaffected by frequency variation if used on this same wave form. Frequency variation would doubtless introduce errors on a different wave form.

Wave-form errors on electromagnetic instruments are not at all serious and in well-designed types do not exceed 1 per cent. Working the iron at a low density may even reduce this error.

The fact that the scale follows a square law makes it crowded at the zero end and open at the upper end. The first mark above zero is usually about 5 or 10 per cent. of the full scale rating.

The sensitiveness of the instrument is increased by using a control spring, slightly weaker than that employed in the D'Arsonval instrument.

The electromagnetic principle is generally adopted for ammeters and voltmeters, but can be extended to wattmeters, power-factor indicators and frequency indicators.

INDUCTION INSTRUMENTS.

The advantage of the induction type instrument is the fact that it posseses the highest torque and has a long scale—300 degrees can be obtained without multiplying devices.

The construction is in some respects similar to the ordinary integrating watt-hour meter. It consists of a spirally-shaped aluminum disk mounted on the shaft which carries the indicating needle. The aluminum disk is free to rotate in the air gap of an electromagnet, the indications being limited by a control spring. The electromagnet comprises a core of laminated iron punchings on which is mounted the winding or magnetizing coils. When the magentizing coils are excited the flux threading the air gap cuts the aluminum disk, inducing eddy currents therein. A short circuited secondary winding is so mounted on the laminated iron core as to produce a rotating field. This phase displacement of the field produces the necessary turning moment for the disk. The required rotating field is secured by placing a short-circuited winding around one-half of each pole, thus giving a shaded pole effect similar to that employed in an alternating-current fan motor. Another method is sometimes employed in ammeters. A secondary winding is placed next the laminated iron core underneath the magnetizing coils and connected to some coils wound around the pole pieces in such a manner as to virtually produce a bi-polar two-phase motor. This secondary winding is short circuited through the coils on the pole pieces and compensates for frequency, wave form and temperature variations.

It will be seen that this latter form of construction, if the frequency increases, the induction will decrease, due to the transformer action, thus allowing the proper amount of current to flow. The torque and resulting indication of the needle will remain unaffected.

If the temperature increases, the resistance of the secondary winding increases, hence the induced voltage and induction are proportionately increased and the necessary compensation secured.

In order to reduce frequency, wave form and temperature errors to a minimum in the shaded-pole ammeter, a non-inductive resistance is connected internally across the instrument terminals, thereby shunting the magnetizing coils. The combination of the magnetizing coils, which are inductive, and the shunt, which is non-inductive, produces the desired compensation. If the frequency should decrease, more current flows in the magnetizing coils, thus maintaining constant torque and indication.

To compensate for temperature, the shunt resistance has the same temperature co-efficient as the aluminum disk. Suppose the temperature increases, the torque is correspondingly diminished by increased resistance of the disk, at the same time, however, the drop across the shunt has increased, thus diminishing the current in the shunt and forcing more current through the magnetizing coils and maintaining the torque and indication constant.

The voltmeter uses neither the secondary winding with its transformer effect or the shunt method to compensate for frequency and temperature. This means that if the voltmeter has very highly inductive magnetizing coils the torque will vary inversely with the frequency, while if the magnetizing coils were highly non-inductive resistance, the torque would vary directly with the frequency, but as the magnetizing coils of the voltmeter consist of many turns of fine wire, they are inductive. By inserting a non-inductive resistance of proper value in series these two extreme conditions may be so proportioned that the effect of frequency variation is negligible. By making this resistance negative or zero temperature co-efficient wire temperature errors are avoided.

The simplicity of construction, high torque and long scale are features which appeal to central-station attendants, causing the induction instrument to come more into the favor of instrument users.

The instrument is not limited to ammeters and voltmetrs, but is already applied to single-phase and polyphase wattmeters, frequency indicators, power-factor indicators and synchronism indicators. While some of the errors and the energy consumption are a trifle larger than in the dynamometer type of instrument, the sacrifice in accuracy is so slight that it is warranted in securing high torque, excellent scale and dead-beat qualities. The frequency errors should not exceed 4 per cent. for ordinary changes of frequency, and the temperature error should be within 1 per cent. per degree centigrade.

Since the torque is proportional to the square of the current in ammeters and voltmeters, an evenly-divided scale is secured by making the aluminum disk spiral in shape, rather than a perfect circle, the shortest radius of the spiral coming at full scale.

News Notes

At the annual meeting of the Philadelphia Electrical Contractors' Association, the following officers were elected: President, Clayton W. Pike; Vice-President, Benjamin L. Cates; Treasurer, M. E. Arnold; Secretary, M. G. Sellers.

The Pennyslvania Electric Assn. will hold its annual convention at Eagles Mere, Pa., September 8-10.

An offer of $430,000 by Herbert Lloyd, president of the Electric Storage Battery Co., K. B. Schley and C. W. Woodward for the Electric Vehicle Co., has been allowed by U. S. Judge Rellstab. The concern was capitalized at $20,000,000.

The American Street Railway Association will hold its annual convention at Denver, October 4-8, instead of October 18-22, as at first announced.

Standard Underground Cable Company, Pittsburgh, Pa., announces that it will remove its San Francisco office from the Shreve Building to the First National Bank Building, on June 15.

The Regenerative Flame Lamp

A. T. MITCHELL

The trend of flame-arc improvements is principally in the direction of longer carbon life, a very essential requisite to the ultimate scheme of utilizing this type of lamp for highway lighting. Since there must be a limit to the physical proportions of any lamp, the length of carbons is necessarily governed by these limitations, and, to compensate for this drawback, the manufacturers of some of the converging-carbon type of flame lamps have made a virtue of necessity by utilizing the multi-carbon or magazine scheme to secure prolonged life. The objections to this construction are so obvious, however, as hardly to merit a serious consideration of their possible adoption.*

The deposits of scoria or slag from the impregnated carbons caused what appeared to be an insurmountable barrier to their use in a vertical or co-axial position, hence the adoption of the converging arrangement, with carbons of small diameter, positive being 9 mm. or eleven thirty-seconds of an inch, and negative 8 mm. Flame lamps designed for the use of vertical carbons of the impregnated type made their appearance as early as 1901, the most notable being that of Andre Blondel. The prevention of scoria deposits in these lamps is accomplished in a more or less satisfactory manner by having the lower or mineralized carbon positive, and the upper or negative pencil composed of practically pure carbon, further assisted by a strong current of air to carry away the deposits while in a gaseous state. The inherent objection of short life, however, still exists, and this form of construction precludes, we believe, the adoption of the magazine feature.

In the regenerative flame lamp the electrodes are placed vertically and in axial alignment, the lower being the positive and containing the light-producing salts, while the upper is principally pure carbon. The composition of the lower electrode is similar to that used in other flame arcs, consisting of a body of pure carbon, in combination with calcium fluorine salts.

The high luminous efficiency of impregnated carbons used in the vertical position was demonstrated in tests with the Blondel lamp for the New York Edison Company. With a current of 3 amperes and arc voltage of 50.3 the mean hemispherical candle was 790, or 0.191 watt per candle. With 5 amperes and 50.3 volts the mean hemispherical value was 1883 candles, or 0.133 watt per candle. These readings were taken without globes. The regenerative lamp shows an even higher luminous flux, as the following comparative values of different lamps indicate. This remarkable efficiency is due apparently to two potential factors. The first is the design of the lower or mineralized carbon. Contrary to the usual practice of constructing this with an outer wall of carbon and core of light-producing salts, the centre is of pure carbon and of fluted or star-shaped sections, with the spaces between ridges filled to the outer edges with the fluorine salts, producing a finished shape which is really octagonal in cross-section, and about 0.875 in. on the largest diameter. This allows a ready disintegration and free volatilization of the metallic salts, and the almost complete elimination of scoria deposits on either electrodes. The upper is round in cross-section and 0.625 in. in diameter.

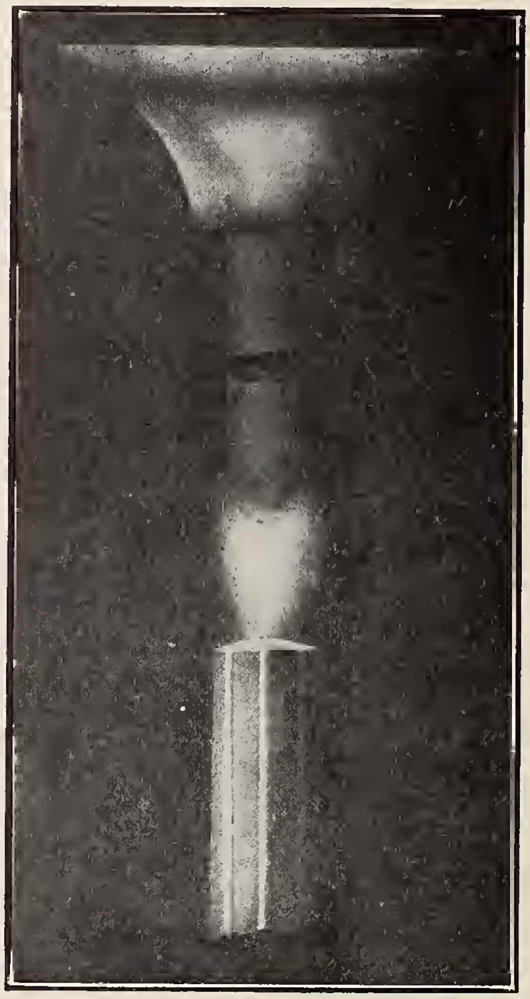

Fig. 1—ARC OF THE REGENERATIVE FLAME LAMP

The second factor is the regenerative feature of this lamp. Unlike other flame lamps of the vertical-carbon type, which allows for escape of the gaseous products of combustion although the heavier elements are sometimes intercepted and held by screens and other devices, this lamp retains the efflorescence of the carbons (Fig. 1), which passes into an upper chamber above the inner globe and from there through side tubes or conductors to the bottom of the globe. In their passage through the side tubes the temperature of the gases is materially lowered, resulting in the less volatile elements settling on the side walls, while the lighter gases are returned into the arc chamber and again mix with the up draft passing through the arc. By the establishment of a steady and uniform current of inflammable gases, with moderate velocity, entering the flame at high temperature, an extremely steady and highly efficient arc is constantly maintained.

The characteristics of mineralized or impregnated carbon arcs were fully described in a paper by Mr. L. B. Marks, read at the convention of the N. E. L. A. in 1906, in which he explained the necessity, with vertical electrodes co-axially arranged, to have the mineralized (or impregnated) carbon below, and forming the positive pole, in order that the vapor of the metallic salts, which produce the bulk of the light, may travel upward and become highly incandescent between the carbon tips.

In the regenerative lamp the intrinsic brilliancy is accentuated and a better distribution secured by the unusual length of the arc, being nominally from 0.75 in. to 1.00 in. with a difference of potential of 70 volts.

By reference to the photometric curves it will be readily seen that the angle of maximum intensity with reflector removed very nearly approaches that of the direct-current enclosed-carbon arc. This will, of course, prove a strong factor in the possible adoption of this lamp for street lighting, with particular reference to business thoroughfares in the larger cities.

Lamps of the converging-carbon type have been barred from this class of lighting, at least in this country, largely on account of the unfavorable distribution.

Not only does the regenerative lamp approach the carbon arc in distribution, but it becomes its counterpart in size of unit, being almost equivalent in current consumption to the direct-current type operating at 5 to 5.5 amperes, or 400 to 440 watts, and the alternating-current type at 6 to 6.5 amperes, or 450 to 490 watts at the arc, with a ratio of about 5 to 1

*N. E. L. A., 1909.

in luminous efficiency in favor of the regenerative lamp.

Two attributes of the carbon arc that assisted largely in their replacement of the old open arcs are possessed by this lamp, namely—favorable distribution of the light flux, and long carbon life, combined with a luminous efficiency that neither of them possessed, and thus forming a most ideal combination for a street-lighting unit.

The nearest approach in luminous power, measured in watts per candle, to the flame arcs, is the metallic electrode or luminous lamp, which, operating at 4 amperes and consuming 300 watts, gives a maximum illumination of about 1200 candle-power, or 650 mean hemispherical candle-power, showing an efficiency of 0.46 watt per candle.

The mean hemispherical candle-power of the regenerative lamp, calculated from the curves shown herewith (Figs. 2 and 3), is 1340, or 0.26 watt per candle. These figures, of course, apply to curves taken with opalescent globe. The total light flux produced by the electrodes is greatly in excess of these values, but much of this is lost through the absorption of the opalescent glass, while in the case of the luminous arc lamp the values given represent practically its

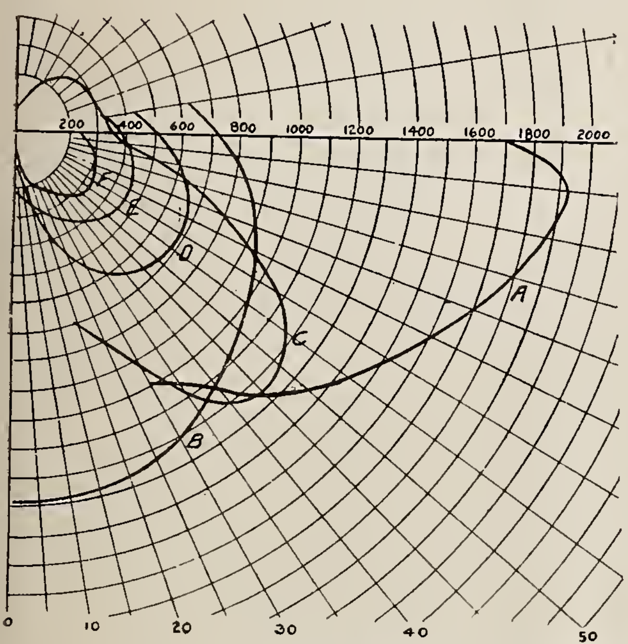

Fig. 2—PHOTOMETRIC DIAGRAM—REGENERATIVE ARC LAMP.

A—Regenerative Flame Arc, Direct Current, 5 Amperes, 350 Watts, 1340 Hemispherical Candle-Power, Opalescent Outer Globe
B—Ordinary Flame Arc, Direct Current, 10 Amperes, 500 Watts, 1070 Hemispherical Candle-Power, Opalescent Outer Globe
C—Open Arc, Direct Current, 9.6 Amperes, 480 Watts, 880 Hemispherical Candle-Power, Clear Globe
D—Series Enclosed Arc, Direct Current, 6.6 Amperes, 480 Watts, 540 Hemispherical Candle-Power, Opalescent Inner Globe
E—Series Enclosed Arc, Alternating Current, 6.6 Amperes, 425 Watts, 390 Hemispherical Candle-Power, Opalescent Inner Globe
F—Multiple Enclosed Arc, Direct Current, 5 Amperes, 400 Watts, 250 Hemispherical Candle-Power, Opalescent Inner Globe

maximum efficiency, as the standard equipment consists of only one globe, and this is invariably of clear glass, at least on street-lighting circuits. The curves for both regenerative and flame arcs with globes removed are shown herewith.

It might be well to explain here that the regenerative lamp is equipped with both an inner and outer globe, the outer being opalescent (Fig. 4).

In Mr. W. D. Ryan's report on specifications for street lighting, submitted at the last convention of the N. E. L. A., he established an X-value of 5.5 for 4-ampere series luminous arcs, as against 4 for series direct-current 9.6 open and 6.6 enclosed and 3.5 for series direct-current 6.6 open and 5-ampere enclosed. At a dis-

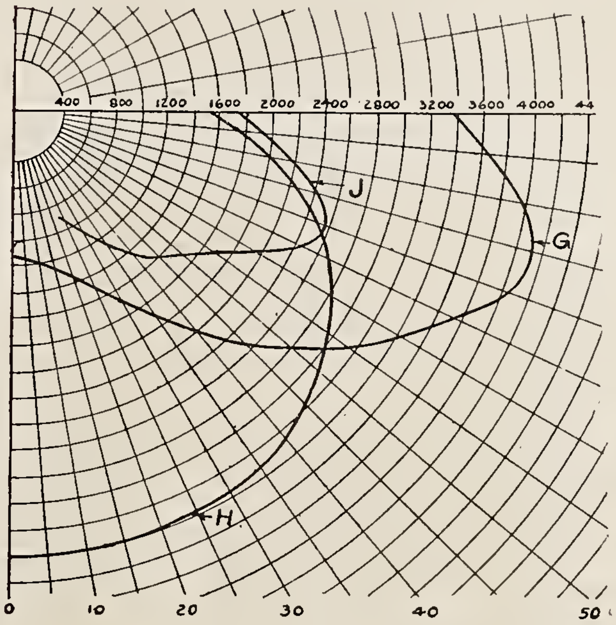

Fig. 3—PHOTOMETRIC DIAGRAM—REGENERATIVE ARC LAMP

G—Regenerative Arc, Direct Current, 7 Amperes, 490 Watts, 2780 Hemispherical Candle-Power, with Outer Globe Removed
H—Ordinary Flame Arc, Direct Current, 10 Amperes, 500 Watts, 3150 Hemispherical Candle-Power, without Globe
J—Regenerative Flame Arc, Direct Current, 5 Amperes, 350 Watts, 1690 Hemispherical Candle-Power, with Outer Globe Removed

tance of 250 feet from the light unit the illumination from the luminous arc is 0.007 foot-candle, while the regenerative lamp, which should be entitled to an X-value of 11, would at the same distance give an illumination of 0.0307 foot-candle, or about 75 per cent. more light than the luminous arc.

While these comparative data, showing the relative value of different units for street lighting, and the remarkable advancement in the art, are interesting, from the fact that they are a most substantial reflex of the indefatigable zeal and intelligent research of those to whom we are indebted for these remarkable achievements, in the perfection of such highly efficient light mediums, it is not the intent of the writer, nor the desire of the manufacturers of this lamp, to advocate its indiscriminate use for street lighting simply on account of its high candle-power and excellent distribution. Such authorities as Dr. Louis Bell and others maintain that for a certain class of streets light units of low intensity and placed sufficiently near together to produce a moderate but uniform illumination are much preferable to units of high intensity placed at street intersections and averaging four or five hundred feet apart. In lighting streets of the first class, or business thoroughfares, however, brilliancy is the chief consideration, with a due regard for the question of maintenance charges. Had human labor and mineralized (or impregnated) carbons been on a par in this country with the prices prevailing in Europe, we should probably not have been so far behind our German cousins in utilizing the flame lamp for this class of lighting, although, as previously stated, the unsatisfactory distribution has militated strongly against its adoption, in addition to the prohibitive cost of the carbons and labor.

The subject of flame arcs has been so comprehensively treated by Mr. L. B. Marks that any attempt on the part of the writer to expatiate on the subject, beyond a few necessary comparisons, might unwittingly lead to a perversion of facts.

We will take the liberty, however, of using his tables showing comparative cost of carbons and maintenance between carbon arcs and flame arcs, both on street circuit burning 4000 hours and commercial circuit burning 1000 hours, substituting the regenerative lamp for the flame arc.

STREET ARCS (500 WATTS) OPERATED 4000 HOURS

	Two Enclosed Arcs	One Regenerative Lamp
Carbons	$2.68	$28.50
Trimming	2.34	1.28
Repairs	1.50	0.75
Inspection	0.90	0.45
Inner globes	0.60	0.30
Outer globes	0.30	0.15
	$8.50	$31.43

It has been assumed in the above table that one regenerative lamp can replace two enclosed arcs. The cost of carbons for the regenerative has been estimated at 50 cents a trim, and for the enclosed arcs at 2.75 cents per trim.

COMMERCIAL ARCS (400 WATTS) AND REGENERATIVE (350 WATTS) OPERATED FOR 1000 HOURS

	Enclosed Arc	Regenerative
Carbons	$0.275	$7.12
Trimming	0.225	0.32
Repairs	0.75	0.75
Inspection	0.45	0.45
Inner globes	0.15	0.15
Outer globes	0.15	0.15
	$2.00	$8.94

Assuming the cost of current at 2 cents per kw-hr., the total cost for operating two series enclosed arcs (500 watts) for 4000 hours would be $80 as against $30 for one regenerative (375 watts) lamp, and the total relative amounts for both maintenance and current $88.50 and $61.43 respectively, showing a gain in favor of the regenerative lamp of $27.07, or figuring on the basis of lamp for lamp, a difference of $17.18 in favor of the enclosed arc; but the regenerative easily redeems itself in a comparison of costs per hemispherical candle-power. Taking this at 1340 gives 0.045 cent per hemispherical candle-power and 10 cents for the carbon arc, taking the candle-power at 440.

In a comparison of values between lamps on the commercial circuit we

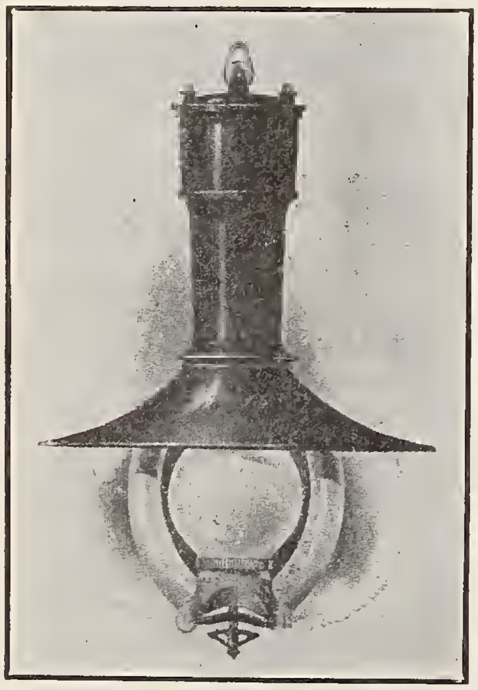

Fig. 4—INNER AND OUTER GLOBES—REGENERATIVE ARC LAMP.

have considered the actual consumption at the arc, current in both cases being 5 amperes and voltage of carbon arc 80, regenerative lamp 70. At 2 cents per kilowatt-hour the cost for 1000 hours is $8.00 and $7.00 respectively, or total costs for current and maintenance $10 and $15.94; but where lamps are intended for interior use, and for such purposes as lighting mills, factories, halls, or for railroad stations, where a more or less concentrated light is preferable, the lamp can be fitted with suitable reflector, and, with a proper elevation above the floor line, one regenerative lamp will easily replace from three to four enclosed arcs and, on account of the penetrating nature of the ray, give more effective illumination. Estimating conservatively and placing the ratio at 3 to 1, a saving of $14.06 per 1000 hours is shown in favor of the regenerative lamp.

The predominance of the orange or yellow ray in mineralized carbons opens up an extensive field of usefulness for lamps designed to utilize these carbons in an economical and efficient manner. The power of this ray to penetrate smoke and fog is well known, and is exemplified by the sun on a very hazy day, when only the red and yellow rays penetrate the smoky atmosphere, the violet and green rays being entirely absorbed and therefore rendered useless. This is an unfortunate characteristic of the carbon arc, which is very forcibly demonstrated under similar conditions at night, due to the predominance of the violet and blue rays. While these advantages are manifest for street-lighting units, they should appeal with special force to those active in the sphere of marine lighting, an illuminant of equal power under all conditions of weather being of prime importance in lighthouses and searchlight work.

In foundries, blacksmith and large erecting shops, where the presence of traveling cranes often necessitates the location of the lighting units at an extreme height from the floors, a good downward illumination can be secured where it is most needed by the workmen, and one not materially affected by the presence of smoke or dust in the shop.

A word in regard to the mechanical details of the Regenerative lamp may prove of interest before bringing this paper to its close.

The sectional view (Figure 6) shown herewith of the multiple direct-current lamp gives a good idea of its general construction. The overall length is 36 inches, and weight about 40 pounds. The movement in both the multiple alternating and direct-current lamp consists of one coarse wire solenoid with an armature of special iron laminated in the alternating lamp; an equalizing lever, encircling the centre tube and pivoted on same, connected at its opposite end to dash-pot, which is rather larger than usual, and equipped with metal plunger, having a ball-and-socket connection to stem. The clutch and lifting rods are of standard design.

In the alternating-current lamp a coil spring is interposed between armature and equalizing lever, to absorb current vibrations.

Connection to upper carbon is made through a coiled flexible copper cable contained in the carbon tube. The lamp mechanism is enclosed in a heavy sheet-copper case and well protected from the weather, as well as from the gaseous products of the arc.

The circulating chamber with side tubes is plainly shown in Fig. 5. The gases pass into this through the top of the inner globe and, becoming heavier from cooling, fall to the bottom of side tubes, at the same time depositing a large portion of the heavier elements on the tube walls and lower portion; the gases re-enter globe at lower end and, being drawn upward by the heat of the arc, repeat the cycle of operation. Outside air can not enter the inner globe, and only to a very limited extent the outer globe.

At the end of a 70-hour run there is a very slight efflorescence on the upper end only of the inner globe, but not sufficient to intercept the horizontal and downward rays or cause any perceptible dimming of the light.

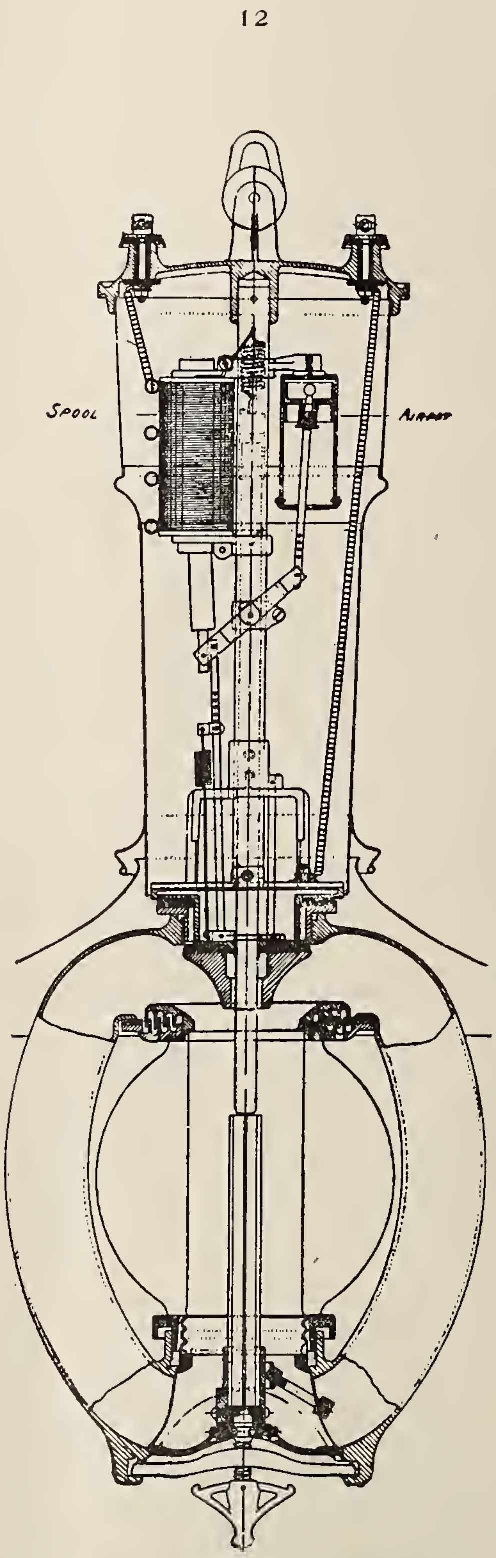

Fig. 5.—SECTIONAL VIEW—REGENERATIVE ARC LAMP.

The lamp is trimmed in a similar way to the ordinary carbon arcs, with closed-base inner and open-base outer globe. The lower, removable section of the circulating chamber serves as a

base for the inner globe, and the two are removed together, as well as the lower carbon, which is held by a thumbscrew and clamp to the removable section. The outer globe remains in position.

The equipment of the lamp includes an external steadying resistance in a separate case or jacket, which can be connected in the line and placed where most convenient. The 220-volt lamps are designed to operate two in series, with sufficient resistance in one jacket. These are identical in construction with the 110-volt lamps, except for the addition of a shunt coil, which is designed to encircle the dashpot, this being made of smaller diameter to allow the necessary space for winding.

It is the purpose of the manufacturers to supply the regenerative lamp for straight series lighting, at least on direct-current circuits, and probably for alternating-current, if the results of the experimental work now under way justify their entering the field.

The perfection of the regenerative lamp, as we find it to-day, marks a new era in the lighting art, or at least that section of it devoted to the development of high-efficiency arc lamps, whose prestige as the most efficient of light-producing units was in danger of becoming seriously impaired by the increasing popularity and high efficiency of the tungsten-filament lamp.

Smokeless Combustion of Coal in Boiler Plants

A bulletin on the smokeless combustion of coal in boiler plants with a chapter on central heating plants will soon be issued by the United States Geological Survey, Technologic Branch, giving in detail a study of the conditions found in industrial establishments in thirteen of the largest cities of Indiana, Illinois, Kentucky, Maryland, Michigan, Missouri, New York, Ohio and Pennsylvania, between 400 and 500 plants having been inspected. Sufficient information was collected to make the data from 284 plants of value for this report.

The bulletin, prepared by D. T. Randall and H. W. Weeks, not only shows that bituminous coals high in volatile matter can be burned without smoke, but also that large plants carrying loads that fluctuate widely, where boilers over banked fires must be put into service quickly and fires forced to the capacity of their units can be operated without producing smoke that is objectionable. Proper equipment, efficient labor, and intelligent supervision are the necessary factors.

The burning of coal without smoke is a problem which concerns the government directly because of the advantages of smokeless combustion both in public buildings and on naval vessels. In addition, smoke abatement is a factor in conserving the fuel resources of the United States, hence, as a part of its general investigation of the best methods of utilizing the coals of this country, the United States Geological Survey has made extended tests to determine the conditions necessary for the smokeless combustion of bituminous coal in boiler plants.

The general conclusions of Messrs. Randall and Weeks are as follows:

Smoke prevention is possible. There are many types of furnaces and stokers that are operated smokelessly.

Credit is to be given to any one kind of apparatus only in so far as the manufacturers require that it shall be so set under boilers that the principles of combustion are respected. The value of this requirement to the average purchaser lies in the fact that he is thus reasonably certain of good installation. A good stoker or furnace poorly set is of less value than a poor stoker or furnace well set. Good installation of furnace equipment is necessary for smoke prevention.

Stokers or furnaces must be set so that combustion will be complete before the gases strike the heating surface of the boiler. When partly burned gases at a temperature of, say, 2500° F., strike the tubes of a boiler at, say, 350° F., combustion is necessarily hindered and may be entirely arrested. The length of time required for the gases to pass from the coal to the heating surface probably averages considerably less than one second, a fact which shows that the gases and air must be intimately mixed when large volumes of gas are distilled, as at times of hand-firing, or the gas must be distilled uniformly, as in a mechanical stoker. By adding mixing structures to a mechanical stoker equipment both the amount of air required for combustion and the distance from the grates to the heating surface may be reduced for the same capacity developed. The necessary air supply can also be reduced by increasing the rate of combustion.

No one type of stoker is equally valuable for burning all kinds of coal. The plant which has an equipment properly designed to burn the cheapest coal available will evaporate water at the least cost.

Although hand-fired furnaces can be operated without objectionable smoke, the fireman is so variable a factor that the ultimate solution of the problem depends on the mechanical stoker—in other words, the personal element must be eliminated. There is no hand-fired furnace from which, under average conditions, as good results can be obtained as from many different patterns of mechanical stoker; and of two equipments the one which will require the less attention from the fireman gives the better results. The most economical hand-fired plants are those that approach most nearly to the continuous feed of the mechanical stoker.

The small plant is no longer dependent on hand-fired furnaces, as certain types of mechanical stokers can be installed under a guaranty of high economy, with reduction of labor for the fireman.

In short, smoke prevention is both possible and economical.

During 1904 to 1906 coals from all parts of the United States were burned at the Government Fuel Testing Plant at St. Louis, in furnaces which were in the main of the same design. Most of the tests were made on a hand-fired furnace under a Heine water-tube boiler. The lower row of tubes of the boiler supported a tile roof for the furnace, giving the gas from the coal a travel of about 12 feet before coming into contact with the boiler surface. This furnace is more favorable to complete combustion than those installed in the average plant. A number of coals were burned in this furnace with little or no smoke, but many coals could not be burned without making smoke that would violate a reasonable city ordinance when the boiler was run at or above its normal rated capacity.

In 1907, the steaming section of the St. Louis plant was moved to Norfolk, Va., where subsequent tests of this nature were made. The plant at Norfolk was equipped with two furnaces—one fired by hand and the other by a mechanical stoker.

In the course of the steaming tests some special smoke tests were made and the influence of various features in smoke production was noted. As the tests were made as far as possible under standard conditions with a minimum variation in boiler-room labor the results bring out the importance of other factors such as character of fuel and furnace design.

A brief summary of the general conclusion is as follows:

A well-designed and operated furnace will burn many coals without smoke up to a certain number of pounds per hour, the rate varying with different coals, depending on their chemical composition. If more than this amount is burned, the efficiency will decrease and smoke will be made, owing to the lack of furnace capacity to supply air and mix gases.

High volatile matter in the coal gives low efficiency and vice versa. The highest efficiency was obtained when the furnace was run at low

capacity. When the furnace was forced the efficiency decreased.

With a hand-fired furnace the best results were obtained when firing was done most frequently, with the smallest charge.

Small sizes of coal burned with less smoke than large sizes, but developed lower capacities.

Peat, lignite and subbituminous coal burned readily in the type of tile-roofed furnace used and developed the rated capacity with practically no smoke.

Coals which smoked badly gave efficiencies 3 to 5 per cent. lower than the coals burning with little smoke.

Briquets were found to be an excellent form for using slack coal in a hand-fired plant. They can be burned at a fairly rapid rate of combustion with good efficiency and with practically no smoke. High-volatile coals are perhaps as valuable when briquetted as low-volatile coals.

A comparison of tests on the same coal washed and unwashed showed that under the same conditions the washed coal burned much more rapidly than the raw coal, thus developing high rated capacities. In the average hand-fired furnace washed coal burns with lower efficiency and makes more smoke than raw coal. Moreover, washed coal offers a means of running at high capacity, with good efficiency, in a well-designed furnace.

Forced draft did not burn coal any more efficiently than natural draft. It supplied enough air for high rates for combustion, but as the capacity of the boiler increased the efficiency decreased and the percentage of black smoke increased.

Most coals that do not clinker excessively can be burned with 1 to 5 per cent. greater efficiency and with a smaller percentage of black smoke on a rocking grate than on a flat grate.

Air admitted freely at firing and for a short period thereafter increases efficiency and reduces smoke.

As the CO in the fuel increases the black smoke increases; the percentage of CO in the flue gas is therefore, in general, a good guide to efficient operation. However, owing to the difficulty of determining this factor, combustion cannot be regulated by it.

The simplest guide to good operation is pounds of coal burned per square foot of grate surface per hour.

None of the problems of combustion have received more experimental treatment than the burning of coal in hand-fired furnaces. Hundreds of devices for smokeless combustion have been patented but almost without exception they have proved failures. This record may be explained by the fact that many of the patentees have been unfamiliar with all the difficulties to be overcome, or have begun at the wrong end. Numerous patents cover such processes as causing the waste gases to re-enter the furnace, and schemes for collecting and burning the soot are legion. So many manufacturers who have been looking for some cheap addition to a poorly constructed furnace to make it smokeless have experienced inevitable failure that the work of educating the public to rid cities of the smoke nuisance has been hard, long, and only partly successful.

The total number of steam plants having boilers fired by hand is far greater than the total of plants with mechanical stokers, but if the comparison is based on total horse power developed the figures show less difference. Particularly is this true in sections of the Central West, where mechanical stokers are generally used at large plants. As a general rule, hand-fired plants do not have proper furnaces, and methods of operation are far from conducive to good combustion. Coal is usually fired in large quantities, and little opportunity is given for the air and gases to mix before the heating surface is reached and combustion is arrested. In all the hand-fired plants visited success in smoke prevention has been obtained chiefly by careful firing. The coal was thrown on often in small quantities; the fire was kept clean, enough ash to prevent the passage of air through the fire never being allowed to collect on the grate; and more air was supplied at firing than after the volatile matter had been distilled. Even with such precautions the plants might have made objectionable smoke at times but for the fact that usually some method was employed for mixing the gases and air before they reached the heating surface.

Some general conclusions from the facts set forth in the bulletin are as follows:

The flame and the distilled gases should not be allowed to come into contact with the boiler surfaces until combustion is complete.

Fire-brick furnaces of sufficient length and a continuous or nearly continuous supply of coal and air to the fire make it possible to burn most coals efficiently and without smoke.

Coals containing a large percentage of tar and heavy hydro-carbons are difficult to burn without smoke and require special furnaces and more than ordinary care in firing.

Briquets are suitable for use under power-plant conditions when burned in a reasonably good furnace at the temperatures at which such furnaces are usually operated. In such furnaces briquets generally give better results than the same coal burned raw.

In ordinary boiler furnaces only coals high in fixed carbon can be burned without smoke, except by expert firemen using more than ordinary care in firing.

Combinations of boiler-room equipment suitable for nearly all power-plant conditions can be selected, and can be operated without objectionable smoke when reasonable care is exercised.

Of the existing plants some can be remodeled to advantage. Others can not, but must continue to burn coals high in fixed carbon or to burn other coals with inefficient results, accompanied by more or less annoyance from smoke. In these cases a new, well-designed plant is the only solution of the difficulty.

Large plants are for obvious reasons usually operated more economically than small ones, and the increasing growth of central plants offers a solution of the problem of procuring heat and power at a reasonable price and without annoyance from smoke.

The increasing use of coke from by-product coke plants in sections where soft coal was previously used, the use of gas for domestic purposes, and the purchase of heat from a central plant in business and residence sections all have their influence in making possible a clean and comfortable city.

Dossert & Company, 242 West 41st Street, New York, report having received the following large orders during the current week: From the Compagnie Egyptienne Thomson-Houston, Cairo, Egypt, 500 cable taps and 500 back connection lugs; from the Western Electric Company for shipment to Johannesburg, South Africa, 300 front-connection lugs, 200 two-ways, 100 three-ways and 100 cable taps; from the United Electric Light & Power Company, 2000 flat-shank terminal lugs for service cut-outs.

B. Elshoff, for 14 years assistant superintendent of the Allis-Chalmers-Bullock Co., of Cincinnati, and for the past two years superintendent of the electrical department of the Allis-Chalmers Co., of Milwaukee, has recently severed his connection with the last-named company. Mr. Elshoff may eventually accept a position with an Eastern firm, but for the present will remain in Milwaukee.

The Anderson Porcelain Company, of East Liverpool, Ohio, have announced to the trade their appointment of the Campbell-Stagg Company, of New York, as Eastern sales representatives.

General Electric Company, Schenectady, N. Y., advises that its Montana office was moved to a new location in the Phoenix Building, Butte, on June 1.

The Practical Aspects of Recent Improvements in Transformers

W. A. LAYMAN

All members of this Association are aware that a very great advance has been made during the last few years in the design and performance of static transformers. The purpose of this paper is to point out the way in which some of these improvements have been secured, as well as to call attention to some of the dangers involved in pursuing the possibilities of the present art to too great extremes. Much of this progress has been the result of a continuous, and, recently, quite sharp improvement in the magnetic quality of sheet steel.*

On this particular subject a great deal of conflicting and confusing trade literature has been published. The latest quality of transformer steel has been exploited under the various advertising names of silicon steel, alloy steel, silico-vanadium, and the like, with claims of individuality for each. The substantial fact is that these names are synonymous. They all refer to a quality of material in which the percentage of silicon has been greatly increased over that previously prevailing in the art. In chemical composition, the best material, as commonly employed in use to-day, shows the following analysis:

	New Steel	Old Steel
Combined carbon	0.07	0.08
Manganese	0.17	0.24
Sulphur	0.023	0.05
Silicon	3.70	0.094
Aluminum	1.314	0.05

It has been known from a very early date in the history of commercial transformers that silicon improves the quality of steel for transformer purposes, and some of the early technical writers explained the non-aging quality of impure steels, as compared with the pure, on the score of the presence of appreciable quantities of silicon. Manufacturing difficulties are said to have held back a quality of steel with as much as 3 per cent. of silicon until about two years ago, when European mills began producing successfully this high silicon material and very quickly its manufacture began here.

The result of this change in chemical composition, together with special heat treatment at the hands of the manufacturer of the steel, has resulted in this marked improvement in the magnetic quality. It will be seen by reference to Fig. 1 that the improvement in internal energy losses of this material as compared with the old is, on the average, about 25 per cent.

It immediately follows that transformers designed with this new material will differ greatly from former types. If the weight is left the same performance will be greatly improved. If performance remains unchanged the weight is largely reduced. Between these extremes there is a wide range of combinations of somewhat reduced weights, with gains also in performance.

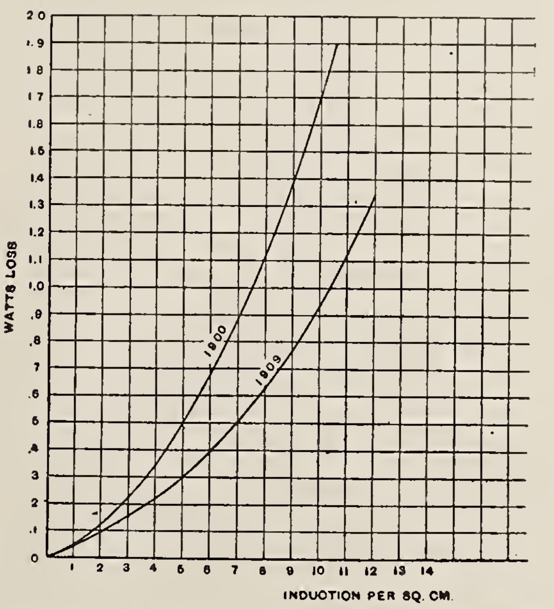

Fig. 1—COMPARISON OF INTERNAL ENERGY LOSSES IN TRANSFORMERS

Manufacturers at the present time are compromising between the two extremes and building transformers lessened somewhat in weight, but substantially improved in performance. The weight feature of present designs, as compared with those of earlier date, is shown in Fig. 2.

A comparison of core losses of the latest high-efficiency types of the leading manufacturers, and like characteristics of the same makes as of five years ago, is illustrated in Fig. 3. A similar comparison of copper losses appears in Fig. 4. It naturally follows that this large reduction in both iron and copper losses results in greatly improved efficiency of the apparatus.

Another great advantage of this new steel, as compared with former grades, lies in the matter of aging. All manufacturers in employing the earlier grades of material were aware that even the best qualities were subject to very considerable differences in the matter of aging characteristics. Some shipments would not age, while others would show considerable deterioration even at low temperature. This new material seems uniformly to be practically non-aging. Numerous tests show a tendency toward a gradual reduction of core loss under the usual operating temperatures, rather than an increase.

The cost of transformers, unfortunately, does not show the same reduction, due to the fact that the new steel costs several times as much as the earlier material. Whether this large increase in cost of material will undergo a sharp reduction as the mills become familiar with it and develop new processes of manufacture, remains to be seen. The assertion is made by the makers that present processes of manufacture are sufficiently more complicated and expensive to justify the high prices at which the steel is sold. The market price of transformers, therefore, has not been substantially modified by the advent of this new steel, and if business conditions were now normal it is probable the cost of this apparatus to central stations would be materially greater than it is at present. The demand for high efficiencies constantly prevails, and it is probable that the actual cost of some existing high-grade transformers is in excess of that prevailing before this new material was introduced, even though the physical dimensions of the transformers may have been considerably lessened.

It is not possible in the time allotted this paper to cover the subject exhaustively. It is hoped, however, that the points touched upon may prove of some suggestive value. Before passing to other phases of this development, the author will perhaps be pardoned if he indicates lines along which caution should be exercised; or, in other words, the abuse that may be made of this new material.

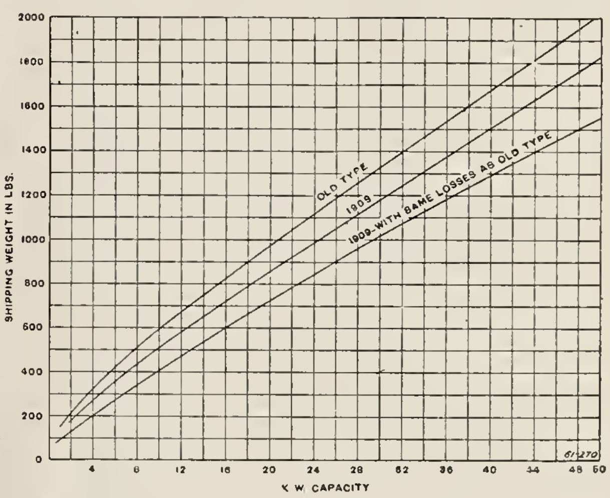

Fig. 2—COMPARISON OF WEIGHTS OF TRANSFORMERS

It is indicated above in general

*N.E.L.A. 1909.

terms that with judicious use the performance may be bettered, the weight reduced, or a little of both. It is also possible with this new steel to produce a much cheaper article. If the transformer be designed for a density of

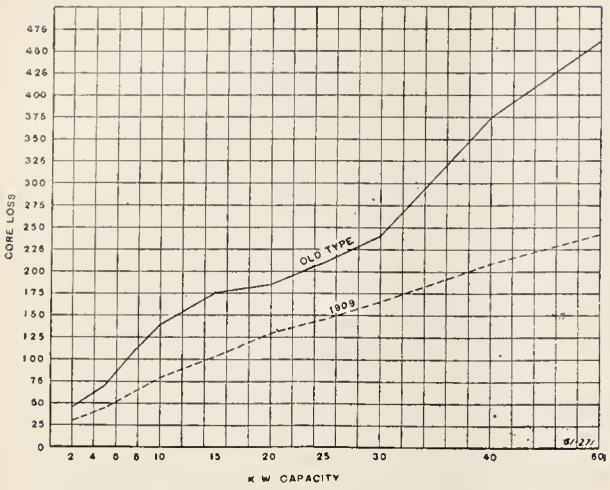

Fig. 3—COMPARISON OF CORE LOSSES IN TRANSFORMERS

magnetic induction above the limits considered desirable for high-grade apparatus, the labor and material cost may be considerably reduced. Such transformers will, however, be subject to pronounced and serious objection by reason of the high magnetizing current absorbed. This magnetizing current, sometimes styled idle or no-load current, in such designs assumes abnormal proportions and is worthy of your careful notice. In the early 90's, before convenient or commercial forms of indicating wattmeters had been brought out, purchasers of transformers watched very closely the idle-current characteristics of all transformers purchased. Nearly all the manufacturers included this idle current in their performance tabulation. With the advent of the convenient portable wattmeter, data as to core losses superseded leakage current. Leakage current has consequently been almost forgotten by the purchaser. There was justification for this in that it was the prevailing practice of transformer manufacturers to hold down this leakage to very low limits.

By reason of the lower losses in the new material for a given induction, it follows that by employing higher inductions the losses may remain the same at reduced cost of manufacture. High induction, however, leads inevitably to high leakage current, and for this reason buyers should revive leakage current as a feature to be considered before making purchases. High leakage current is a dangerous thing. Under excess voltage it rises rapidly. It is rumored that, since the advent of this new steel, transformers have been placed upon the market with leakage current under normal pressures running as high as 20.25 and 50 per cent. In a few alleged instances of rejection this has run as high as 100 per cent. of full-load current. Of course, no reputable manufacturer intentionally put out any such grade of apparatus, and probably nothing of this kind is being manufactured in the United States at the present time. However, the elimination of leakage current is worthy of the central station man's attention, as transformers may be suplied with low losses and still have very high leakage characteristics.

At this point it may be of interest to note just what the improvement in performance characteristics of two or three sizes of distributing transformers amounts to in dollars and cents. This is shown in tabulated form, as follows:

Size, Kw.	All-Day Losses 1905 High-Efficiency Transformer Watt-Hours	All-Day Losses 1909 High-Efficiency Transformer Watt-Hours	Gain in Watt-Hours per day	Savings per Year at 1.5 Cents per Kilowatt-Hour
1	903	610	293	$1.60
10	4,187	2,646	1 541	8 43
50	14,415	8,760	5.655	30.96

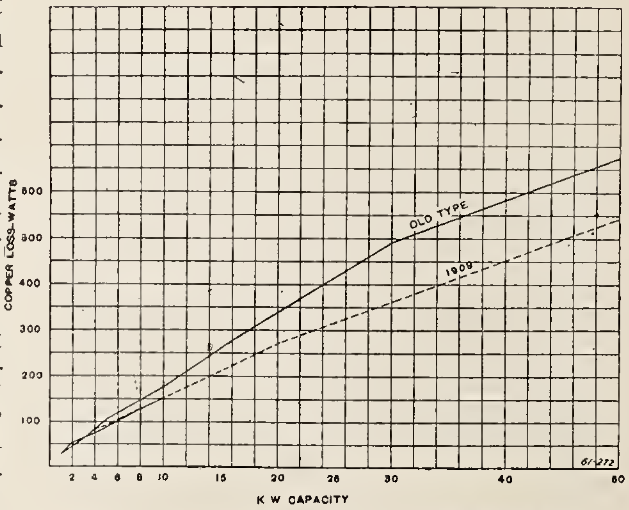

Fig. 4—COMPARISON OF COPPER LOSSES IN TRANSFORMERS

The above calculations were made on the basis of 24 hours' core loss, 5 hours' copper loss.

The great change in physical dimensions of transformers permits of a considerable improvement in regulation, if the manufacturer or user desires it. This follows from the great reduction in copper loss it is possible to secure. As a matter of fact, however, designers of commercial transformers are not taking advantage of the possibilities in this direction, as to do so might render the new transformer incapable of operation in multiple with previous types.

Parallel operation of units of this class is a very important factor to the central station. The successful parallel operation of two or more transformers is dependent upon two factors—copper drop and reactance. The effect of these two factors in combination is usually referred to as the impedance of the transformer. Correctly speaking, transformers of the same size when operating in parallel divide their load in the inverse ratio of their impedance. Manufacturers could, therefore, with advantage to the central station, publish in their tables of data the impedance of their standard sizes. With this information before him, the user could definitely determine the division of load under parallel operation of different sizes or different makes. Those with the same percentage impedance will divide the load in proportion to their kilowatt capacity.

In the light of present-day possibilities in the manufacture of transformers with close regulation, it is exceedingly interesting to read some of the patents and also trade journal discussions of the early days dealing ponderously with the difficulty of securing good regulation at all.

It may be permissible at this point to suggest good care in the making of all connections in the secondary circuit. A poor connection may introduce enough additional drop to cause a very unequal distribution of the current between two transformers that would otherwise divide the load equally. Too much importance can not be placed upon the last statement. The line resistance between the secondaries of various transformers in a network is of equal importance. Other things being equal, the transformer nearer the centre of distribution will take the larger proportion of the load.

The natural effect of lower losses in present-day transformers has been to lessen the heating problem. With the reduction in physical dimensions of active parts and a lessening of the losses, smaller jackets may be em-

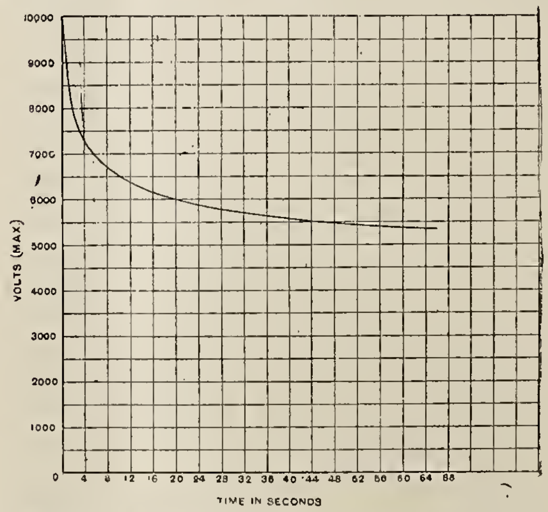

Fig. 5—TIME-PRESSURE CURVES FOR INSULATION TESTS

ployed. Conditions have so changed as to eliminate the heating question entirely in the smaller sizes; that is to say, manufacturing considerations

dictate cases of such sizes that the transformers have abnormally small temperature rise.

While reduction in physical dimensions is of benefit to the user and in some ways lessens the difficulty of manufacture, it has in others increased the difficulties. It has given rise to the necessity for increased care in the internal insulation, and it is therefore wise to give most careful consideration to any existing practice that may have a tendency to impair the insulation unnecessarily. This leads to a consideration of proper in-

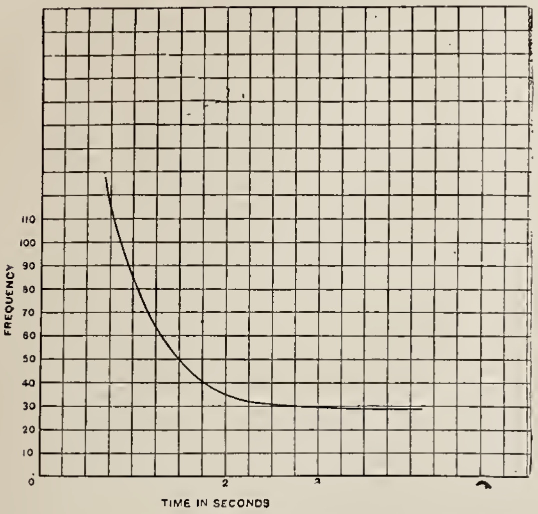

Fig. 6—TIME-FREQUENCY CURVES FOR INSULATION TESTS

sulation tests. Enough attention has not been given heretofore to the ill effects of prolonged application of test pressures, and the experimenters are now closely studying this phase of the work. These investigations are bound to result in material benefit to the manufacturer and the user. Professor A. S. Langsdorf, of Washington University, St. Louis, published some months ago a very instructive paper on the ill effects of insulation tests of long duration. He finds as the result of a long series of tests that all the ordinary insulating materials reach a condition of normal resistance to puncture within 10 sec. after an alternating pressure has been applied. This normal resistance is about one-half the instantaneous resistance. The application of test pressure beyond this interval of 10 sec. simply results in the impairment of the insulation. A given insulating material that will withstand succesfully a pressure of 10,000 volts for two to five seconds may break down on that pressure if tested for a period of five minutes, and between these limits of five seconds and five minutes there is a continuous, gradual deterioration or fatigue of material. It is therefore evident that insulation tests should be limited to intervals that correspond approximately to the duration of the sudden and usual stresses arising in the supply cricuits, and it is probable that an insulation test of 10 seconds is amply sufficient to discover all the defects existing in an insulating material in this apparatus, and that a test of longer duration is not only of no benefit, but results in a gradual impairment of the insulation.

In the same way an increasing frequency is shown, by Professor Langsdorf's test, to be equivalent to an increase of pressure. In describing higher frequency under which insulation tests are to be made, the multiplying factor due to this increase of frequency should be taken into consideration. Professor Langsdorf's test as to the time a given material will stand a given pressure is shown in Fig. 5. Fig. 6 shows the relation between frequency and time, the voltage remaining constant. An increase of frequency, therefore, is equivalent to an increased time of application. It is the author's recommendation that all users take advantage of this information and reduce the requirements for insulating testing, for periods of 10 to 20 seconds, and, further, that the prescribed pressures be double the normal operating pressure. This recommendation applies more particularly to transformers wound for the higher voltages, as it is the custom of all manufacturers to test their standard central station units at 10,000 volts.

One of the most interesting, but not important, effects of recent improvements has been to emphasize the principle that the user is not particularly interested in the type; that is, whether shell or core type is employed. Determination of this feature should be left entirely with the manufacturer, as the choice between the two is more a matter of habit than of engineering preference. Some years ago manufacturers of transformers were divided somewhat violently as between the core and shell type of construction. The partisan advocates of each were strongly disinclined to see any merit in the other. It is interesting now to see that some of the shell-type advocates of former years are adding core types to their lines, while some of the most ardent core-type advocates have switched around to shell type. The meaning of this is that the statements frequently made as to the virtues of one or the other type were advertising, rather than facts. Each offers a compromise under certain conditions, and a skilful designer can come very near accomplishing the same result in both types. In the writer's opinion, the user is largely interested in the quality of what he gets, and if he will observe carefully the performance results he will not concern himself particularly whether the apparatus is shell or core type.

Sufficiency of Demand for Electricity

Section 65 of the New York Transportation Corporations Law imposes a penalty of $10 and a further sum of $5 a day for the failure of an electric lighting corporation to furnish electricity after an application in writing by the owner or occupant of any building or premises, the penalty to be paid to the applicant. In a recent case, where a consumer's electricity had been cut off, he wrote demanding a supply, but the company insisted on his signing a special contract. The court held that a mere request to restore the connection and furnish the current on the same terms and conditions as before was a sufficient demand.

Moffat *v.* New York Edison Co., 116 N. Y. S. 683.

ACTION FOR RELIEF FROM DAMAGES.

An action was brought by an electric light and power company, the complaint in which contained the following allegations, to which the defendant demurred on the ground that it did not state facts sufficient to constitute a cause of action. The facts stated were as follows: After the plaintiff company had constructed its line the defendant, a telephone company, strung wires over the plaintiff's wires in a defective manner, both as to method and material; no precaution was taken by the defendant to prevent these wires from falling or sagging and coming in contact with the plaintiff's wires; a building to which the telephone company's wires were attached was destroyed by fire, and the wires of the two companies came in contact, causing the current in the plaintiff's wire to be transmitted along the telephone wire, resulting in personal injury to a third person; for some time prior to this ocurrence the telephone company's wires had been in disuse; it had been notified by the owners of buildings to which the wires were attached to remove them, but had refused to do so; the plaintiff had no knowledge nor means of knowing of the defective condition of the telephone company's wires; the accident was claimed to be solely due to the negligence of the telephone company; the person injured recovered judgment against both companies, and through a collusive arrangement between the telephone company and this person the amount of the judgment was collected from the plaintiff. The court held that these facts showed a sufficient cause of action. It was also held that counterclaims by the telephone company for amounts paid by it in settlement of actions by other parties arising from the same acci-

dent were insufficient, because they did not show that the telephone company was not connected with the act or omission which ocasioned the injuries for which it was compelled to pay.

Fulton County Gas & Electric Co. *v.* Hudson River Telephone Co. (Supreme Court, Appellate Division, Third Department) 114 New York Supplement, 642.

CONTRIBUTORY NEGLIGENCE OF INJURED PERSON.

In an action to recover damages for the death of a lineman in the employment of a telephone company against an electric light company it appeared that the telephone company had permitted the electric light company to stretch a guy wire from one of its poles to a pole of the telephone company and to attach to its poles and there to maintain wires for the transmission of heavy currents of electricity, one of these wire being defectively insulated. The plaintiff's case, as shown by the evidence, was that the deceased was directed to climb the pole in question to put in its proper place a telephone wire which had been displaced by a falling limb. In carrying out his instructions, when he reached the proper height upon the pole, he abandoned the stirrups provided and stood upon the guy wire, and so standing attempted by means of a hand rod attached to the detached telephone wire to throw that about the electric light wire and draw it over into place; in doing so the guy wire, being attached to the pole so as to be in contact with the metallic blade, which was connected with a trus rod to add stability to the pole, and his hand touching an electric light wire charged with a heavy current at the point where the insulation was defective, although the defect was not apparent, he established a connection which carried the fatal current through his body.

The court held that with respect to the joint use of the pole, each company was charged with the same duty toward employees of the other as toward its own, and the coresponding duty of the employees to use due care for their safety was the same as to both companies; and as the deceased would not have been injured had he not voluntarily and unnecessarily used an appliance for a purpose other than that for which he knew it to be intended.

Cincinnati Gas & Electric Co. *v.* Archdeacon (Supreme Court of Ohio) 88 North Eastern Reporter 125.

A case similiar in principle to the above was recently decided by the Texas Supreme Court, in which it was held that where a city owning a lighting plant runs its wires along a partition wall above the roof of a building it is the city's duty to the owners and those having a legal right to use the roof to maintain the wires in a safe condition, but it is not liable to a police officer who, without the knowledge or consent of the owners of the building, goes upon the roof at night to detect persons violating the law and is injured by contact with an improperly insulated wire.

City of Greenville *v.* Potts, 107 South Western Reporter, 50.

ELECTRICAL PATENT CASES.

In Leonard *v.* Cutler-Hammer Manufacturing Co. the Circuit Court of Appeals for the circuit has decided that the Leonaard patent No. 673,274 for an electric circuit-controller, combining in the same device an overload and an underload switch, claims 1, 6, 7 and 11 are void for lack of invention in view of the prior art. Claim 10, if given a broad construction, was also held to be void for lack of invention. If limited to the form shown and described in the drawings and specification it was held not to be infringed.

In Hall Signal Co. *v.* General Railway Signal Co., the Circuit Court of the Western District of New York decided that the Wilson patent No. 470,813 for an electric railway signal apparatus was not anticipated and covers a combination which was the final step in making the normal danger system of signaling successful and practicable and is entitled to rank as a pioneer in the art and to a broad construction. For this reason it was also held to be infringed by the defendant and an injunction and accounting was granted.

In a suit by the General Electric Co. against the Morgan-Gardner Electric Co. decided by the Circuit Court of Appeals of the Seventh Circuit the Knight and Potter patents Nos. 587,441 and 587,442 for a means and method of regulating the power and speed of mechanism driven by two electric motors, the invention consisting of changing from series to multiple by shunting one of the motors, while protecting the other by resistence in series with it, and then breaking the circuit of the shunted motor and arranging it in parallel with the other, were held valid and infringed and an injunction and an accounting were ordered, reversing the decree of the Circuit Court for the Eastern Division of the Northern District of Illinois.

In a patent suit for injunction and accounting for infringement it appeared that the complainant owns patent No. 606,015 for an improvement in systems of electrical distribution and regulation. It named as defendants the Allis-Chalmers Company and the Bullock Electric Manufacturing Company, but the latter, an Ohio corporation, was not served with process and did not appear and the suit was against the Allis-Chalmers Co. alone.

The bill charged, and the answer admitted certain facts as to the ownership by the Allis-Chalmers Company of the majority of the stock of the Bullock Electric Manufacturing Company and its control of the acts of the latter company. The only infringement referred to in the complainant's briefs or proofs was one founded on a sale by the Bullock Company to the Merchants' Heat & Light Company of Indianapolis of certain machinery said to embody the invention of the complainant's patent.

The court held that the ownership of a majority of the capital stock of the Bullock Company by the Allis-Chalmers Company, the fact that some persons—how many does not appear—were members of the two boards of directors, and the fact that the Allis-Chalmers Company advertises that its electrical department is operated by and that it will continue to manufacture the product of the Bullock Company, taken with the averment that it does not in any wise control the Bullock Company except as it lawfully may, as a majority stockholder thereof, were not admissions that the Allis-Chalmers Company controls the Bullock Company in such manner as to justify a conclusion that it is guilty either of direct or contributory infringement; and as the admissions of the answer were the only proofs on the point, the bill was dismissed.

Westinghouse Electric & Manufacturing Co. *v.* Allis-Chalmers Co. (Circuit Court, New Jersey), 168 Federal Reporter, 91.

Questions and Answers

Question.—*I wish to test a number of batteries of dry cells from remote points with a pocket ammeter. What is the effect of testing three to six in series? Would this reading be the average of the cells in the battery?*

Answer.—The wording of your inquiry would give us to understand that you are perfectly familiar with battery testing, but have a doubt about results, due to the fact that you had to test from a distance. Of course, testing near or far does not alter the case, except for the additional resistance of the testing leads, which must be allowed for.

Dry-battery work carries with it the rule of thumb. For all practical purposes the current of any number in series would be the average of each. If too much or too little simply add or subtract cells, which is cheaper than calculating out what the exact number ought to be.

Question.—*Recently we have been considering the addition of a Tirrel regulator to govern our exciter. We have been informed by the maker of the regulator that our exciter will have to be replaced by a larger one. Why is this necessary? Our present one has now been in use eight years and has been plenty big for our worst condition.*

Answer.—The object of having a new exciter is to provide extra capacity in the exciter and to get a machine wound for from 140 to 150 volts. The name plate would call it a 125-volt exciter, but actually it could develop the higher voltage. The reason for the above is to have an exciter which, when delivering normal full-load exciting current to the generator, will itself be underloaded. A fully loaded exciter being under a condition of full saturation would alter its field slowly in response to the action of the regulator. When partly loaded it responds almost immediately to the regulator.

Question.—*We have a new three-phase induction motor which is giving us trouble. We start it about 20 times per day. On an average of once in a dozen times it will refuse to start, although the starting load is well within its range. When we turn the rotor by pulling on the belt it starts off. Why does it stick?*

Answer.—Undoubtedly this motor had one or more dead points in it. Sometimes the magnetic poles of the stator and rotor windings will frame up in such a way as to produce no torque between them. A slight rotation of the rotor usually upsets this condition and the rotor moves off. You cannot repair this yourself. Notify the manufacturer, who will give you a rotor of a different number of slots.

Question.—*Is there any record of gas-engine sales, particularly covering the use of electric ignition?*

Answer.—We know of no record of these sales.

Question.—*We have 150 h.p. actual load running in our mill. Power has been furnished single phase by the G— S— Co. We are now to put in our own plant, but find that engine-type single-phase generators are not on the market. This will require our purchasing a two- or three-phase generator. In case we buy the latter, what should be the capacities of the engine and of the generator?*

Answer.—To cover losses of the engine horse power should be a fifth larger than the motor capacity, or about 180 h.p. This is on the assumption that 150 h.p. in the motors is about the peak of the load.

A three-phase generator is good for 70 per cent. of its normal capacity when used as a single-phase machine.

$$\therefore 156 = \frac{70}{100} \text{ of total capacity.}$$

$$\frac{156}{70} \times 100 = 222 \text{ h.p. (approximately).}$$

$$222 \text{ h.p.} = \frac{222 \times 3}{4} = 167 \text{ k.w. (approximately).}$$

Therefore, the generator should be the next standard size above, or say a 200-h.p. engine and a 1.75-k.w., three-phase generator.

Question.—*Rheostats for direct-current motors have many contacts. How is it that the starter for an alternating-current motor has only two points, "starting" and "running"?*

Answer.—A rheostat is cut into the armature circuit of a direct-current motor in order to make an artificial resistance to take the place of the counter electromotive force. The resistance of a direct-current armature is a small fraction of an ohm. Suppose one with 1/10 ohm resistance were put across a 220 V circuit. The flow of current would be $\frac{220}{.1} = 2200$ amperes. As ordinary armatures are wound with wire seldom exceeding No. 2 (B. & S. gauge) it is evident that, if the fuses held, the armature would go up in smoke very quickly. When the armature is at full speed the "dynamo current" of the motor, or its counter electromotive force, as commonly called, bucks the driving current and reduces the number of amperes actually flowing, according to the horse-power capacity of the motor. This counter electromotive force builds up with increase of speed, so that the rheostat should have its resistance cut out in proportion to the increase.

With an alternating-current motor the case is different. An induction motor is practically a transformer with the secondary free to move. Like a transformer, any size machine can be thrown directly across the line without injury. But when such a motor at rest is thrown across the line the power-factor is so low it will momentarily try to draw from three to six or eight times the number of amperes (not horse-power) to start the motor as will later be required to develop full horse-power. As speed increases the power-factor improves, so that the running amperes are about the same as a direct-current motor of similar horse-power would consume when working on a like voltage. As this starting rush of amperes is in proportion to the voltage, it is evident that half voltage would give only one-half as many amperes, starting torque being reduced, of course. The alternating-current motor starter, commonly known as a "compensator," or as an "auto-starter," is really a lowering transformer. The "starting" posititon is usually placed so as to allow only 60 per cent. of normal voltage coming on the "running" point. In large-sized motors a number of different taps into the transformer (starter) are used so as to give 60 per cent., 70 per cent., 80 per cent., 90 per cent. and 100 per cent. in turn, thus giving a very easy start without disturbing the whole supply system by a heavy sudden draft of amperes. The starting regulation, however, never need be so close for alternating-current apparatus as for direct-current apparatus, owing to the presence of self-inductor in the former. Hence the lesser number of points or leads.

The Macbeth Iron Company, of Cleveland, engineers, founders and machinists, builders of blowing engines, etc., and The Bruce-Meriam-Abbott Company, also of Cleveland, builders of gas engines, were consolidated on June 1st, the name of the new company being the Bruce-Macbeth Engine Company.

It is the purpose of the new company to continue the business of both of the former companies on a much larger scale, and to concentrate the two present plants at the former plant of The Macbeth Iron Company on Center Street, Cleveland.

The officers of the company are as follows: President, W. C. Bruce; Vice-President, C. W. Kelly; Secretary-Treasurer, C. J. Snow; Manager, C. E. Curtiss.

The Gould battery in isolated plants is dealt with in a pamphlet sent out by the Gould Storage Battery Co., of Depew, N. Y. The selection of the proper battery, the method of operation, charging rates, and details of installation, are all dealt with, the various types of cells and installations being well illustrated.

News Notes

Among the orders recently received by the Crocker-Wheeler Company, of Ampere, N. J., are several for large direct-current generators. One of these called for a 1500-kw., 550 volt direct-current machine, which is to be used in the machine-shop department of the Union Stock Yards of Armour & Co., Chicago. A similar machine with a rating of 800 kw. at 575 volts was sold to Landers, Frary & Clark, of New Britain, Conn. Warner Bros. Co., Bridgeport, Conn., has placed an order for two direct-current generators, having a capacity of 150 kw. and 329 kw., respectively, at 235 volts. Among other sales are the following: one 150-kw., 125-volt generator to the Keystone Steel & Wire Co.; one 140-kw., 240-volt generator and six 15-h.p., 230-volt motors to the Napier & Mitchell Manufacturing Co., Belleville, N. J.; one 125 kva., 3-phase, 60-cycle, 240-volt alternating-current generator to be installed at the plant of the Cleveland Worsted Mills Co., Cleveland, O.; one 165-kw., 3-phase, 60-cycle, 240-volt generator to the Miami Valley Knitting Works, Hamilton, O. Two 110-h.p., 230-volt direct-current motors were sold to the Illinois Steel Co., South Chicago, Ill. A sale amounting to 247 h.p. in 220 volt direct-current series wound crane motors was made to the Northern Engineering Works at Detroit, Mich. 102 h.p. of 220-volt direct-current motors are to be shipped to the Cen-

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NOTICE TO ADVERTISERS

Insertion of new advertisements or changes of copy cannot be guaranteed for the following issue if received later than the 15th of each month.

CONTENTS

Batteries for Railroads

For many years it has been an open secret that the storage battey is not an economic success where used for supplying propulsion current to railroad trains. Batteries have been used on traction systems to insure against interruption of traffic and to equalize the load on generators. When these two purposes are analyzed to their commercial elements it is found that they resolve themselves into the substitution of batteries for an equivalent capacity of generating and transmitting equipment and experience has amply demonstrated that it is more economical to have the extra equipment than to have the battery.

This stand has been consistently maintained by L. B. Stilwell, H. G. Stott, and other prominent engineers who have handled large installations and in view of this fact the large installation of batteries planned by the New York Central R. R. was somewhat surprising to the majority of electric railroad men. It is somewhat significant, however, that the new substation being built by that company at Tuckahoe is without the usual battery house which has hitherto characterized their designs.

It does not require any unusual acumen to discern the reason for the trend in railroad battery affairs. It has been briefly stated above; we shall now consider it in greater detail below.

The cost of a very large storage battery with housing, boosters, transformers and other accessories is about $65.00 per kw. at the one-hour rate. For smaller batteries used on railway work this figure may be increased as much as 50 per cent., but we shall use the smaller figure in our calculations. Based on the eight-hour rate, the corresponding cost of a large battery and accessories would be from $40.00 to $45.00 per kw.

The one-hour rate should be used as the basis of comparison between batteries and rotating equipment for reasons which will be adduced presently.

The average cost of generating and converting equipment is approximately as follows:

TABLE I

Source of Current	Cost per Kilowatt Continuous Rating	8 Hr. Rating	1 Hr Rating
Power Stations.......	$90	78	45
Substations and transmission equipment..	40	35	20
Total.............	130	113	65

8 Hr. and 1 Hr. Costs based upon Table IV.

The comparative cost of batteries and rotating equipment is as follows:

TABLE II.

Source of Current	Cost per Kilowatt 8 Hr. Rating	1 Hr. Rating
Battery........................	45	65
Rotating equipment (see Table I)	113	65

It is apparently the eight-hour comparison which has misled the unwary. The fair basis of comparison is the one-hour output, as stated above.

When a generating station is equipped with units to carry the eight-hour load, it seldom has sufficient capacity to carry the one-hour or the peak loads. This is a matter of experience. Thus in a specific instance the loads were as follows:

TABLE III.

Duration of Load.	Kilowatts
24 Hours...........................	400
8 "	500
2 "	1000
1 "	1300
1 Min............................	2000

The average overload capacity of rotating equipment, that is generators and rotary converters, is approximately as given in the following table:

TABLE IV.

Duration of Load	Per Cent of Rated Load which may be carried.
24 Hours......................	100
8 "	115
2 "	170
1 "	200
1 Min......................	250

Hence if rotating equipment were installed to carry the eight-hour load, its rating would be 500 kw. and its loading at other loads would be as follows:

TABLE V.

Period	Output of 500 Kw. machines for various periods	Loads to be carried for various periods
8 Hours...............	575	500
2 "	850	1000
1 "	1000	1300
1 Min...............	1250	2000

It is obvious from this typical case that the eight-hour rating is useless as a criterion for the determination of the rating of equipment.

Let us now consider the one-hour rating, which would require a standard rating of $\frac{1300}{2} = 650$ kw., or as this is not a regular size, let us say 750 kw., which permits the use of three 250-kw. units. The loading would then be as follows:

TABLE VI.

Period	Output of 750 Kw. machines for various periods	Loads to carried for various periods
8 Hours...............	865	500
2 "	1275	1000
1 "	1500	1300
1 Min...............	1870	2000

This is seen to be a fair choice of units, the loads being slightly less than the maximum which can be safely carried by the machines.

Suppose the eight-hour rating to have been selected and the peaks carried by batteries instead of dynamo equipment. The required battery ratings would be as follows:

TABLE VII.

Period.	Kilowatts to be carried by battery if latter is based on one hour load.
8 Hours......................	25
2 "	150
1 "	300
1 Min......................	750

Now the discharge rates of batter-

ies for various periods are as follows:

TABLE VIII.

Period	Discharge Rates of batteries for various periods
8 Hours	100%
2 "	260
1 "	400
1 Min.	1000

If we choose a battery on the basis of its eight-hour rate, it will be a 25-kw. battery and its discharge rates for various periods would be as follows:

TABLE IX.

Period	Discharge Rate of Battery Kw.	Load to be carried Kw.
8 Hours	25	25
2 "	65	150
1 "	100	300
1 Min.	250	750

It is obvious from this that a battery rated to carry the eight-hour load would be absurdly small. Rated according to the one-hour load, the following results are obtained:

TABLE X.

Period	Discharge Rate of Battery, Kw.	Load to be carried, Kw.
8 Hours	75	25
2 "	195	150
1 "	300	300
1 Min.	750	750

This is seen to be a fair choice of battery, the loads to be carried being slightly less than the corresponding discharge rate of the battery.

We do not contend that in every case the proper basis of comparison is the one-hour rating, but we do contend that it is usually the correct basis and that the eight-hour rating would be utterly absurd in the great majority of cases.

Returning now to Table II., we see that on the one-hour rating batteries are on a par with rotating equipment as far as initial cost is concerned and we have been more generous in our estimate of the cost of rotating equipment than in our battery estimate. In fact our battery estimate is based upon the lowest price we have heard of.

While the battery is not economical in first cost, it is most decidedly uneconomical in operation.

T. C. Parsons and W. Preece conservatively estimate the life of a storage battery as 15 years with a 10 per cent. residual value. The proper maintenance of a battery therefore requires the replacement of approximately 6.50 per cent. of its original cost every year. Add to this the labor of making these replacements and the labor of maintenance and it will be found that the annual expenses in connection with a battery exceed 10 per cent. of its original cost and are often as high as 15 per cent., nearly all of this being additional to the regular station expenses.

As we go to press we hear a confirmation of our views, in the reported abandonment, as a regulating battery, of one of the largest railroad installations in the country, together with the report of the assignment of these batteries to their "insurance function" only—reason excessive cost of maintenance.

There was once a man who said that the story of Jonah being swallowed by the whale was more than he could swallow and for this opinion he was tabooed by his erstwhile friends who declared that he was denying religion, advocating murder and the disintegration of society. We hope that no angry believer in batteries will follow the example of these people and denounce us as opposed to the general use of batteries and to good engineering in general. We believe in batteries for telephony, where they have made possible the great central battery systems of the present day. We believe in batteries for isolated lighting plants which would be impossible without them. We believe in batteries for train lighting where they replace the objectionable Pintsch gas apparatus. We also believe in batteries for lighting stations where good regulation is requisite and insurance against darkness is worth paying for, but we do not believe in batteries as adjuncts to traction substations except in very special cases.

The Small Central Station

Throughout the rather thickly settled states are several thousand small central stations, if we may properly dignify by that name power stations working during the night time only and delivering a few hundred kilowatts of current for sundry lighting purposes.

For the most part, these little stations are built with cheap machinery as small plants cannot generally afford to install a relatively expensive fuel-saving equipment. They have usually sprung into existence as the hasty plan of a borough council to place electric lights on their streets, and not as the result of a well-developed business plan to build an electric property to supply light and power to a community. Usually the cost of current is so high that the charge to a private consumer is high and relatively few of them get on the circuit of the local company. Consequently municipal lighting is the plum of the small station and not the persimmon it usually is in many of the large cities.

The excessive cost of current generated by cheap plants with all of the attendant unreliability of service is the plain truth before any of these small plants.

The present situation has many points of similarity to the development of the telephone business which began more than a decade before the electric lighting industry. For a period of twenty years the number of telephones in service increased rather slowly down to about 1895 when almost by magic the number began to increase at the phenomenally high rate of 30 per cent. per annum and maintained that rate for nearly a decade. In the case of the telephone, there was slow growth during what may be termed the experimental period of development when people were only getting to know the time-saving telephone. There were neither extensive local systems nor were the connections between towns and cities numerous. Just as soon, however, as communities began to be connected together there was a very rapid increase of the number of calls, and that meant revenue—and there was the already mentioned phenomenal increase in the number of telephones.

A similar expansion of the electric light industry is now about to take place. In practically every town of over 1000 people there is some sort of an electric outfit whose chief economic purpose has hitherto been to make its denizens acquainted with the electric light known generally to them as a thing of luxury for rich folk. Undeniably this has been the general impression of rural communities. But we are now on a new era in the development of electric lighting and power. The same development which took place in the telephone field is in almost full swing in the electric industry. Already water power properties are interconnecting towns with an efficient and reliable service, which if not a cheap service to the public can be made so. Progressive steam plants are throwing out trunk lines to small towns offering them day and night service with steady current and reasonable rates therefor. The larger power distributing companies are delivering current to small towns at rates much lower than the generating costs possible in plants such as a small community could afford to build.

These are the facts, and they are being rapidly understood by the smaller stations. C. C. Custer of the Miami Light, Heat and Power Co., Piqua, O., declared before the Ohio Electric Light Association: "If your town is too small to support a well-built plant, it were better to 'hitch your wagon to a star' of greater magnitude by running a transmission line to a larger plant." In another paper presented before that body this year, C. Smith, manager of the Bradford & Gettysburg, Electric Light and Power Company, Bradford, O., describes such a transmission plant designed to serve Bradford and Gettysburg, taking current therefor from the Greenville Electric Light and Power Co. His paper appears elsewhere.

Meters

An Elementary Explanation of their Underlying Principles, and Methods of Testing

BURLEIGH CURRIER

The function of a meter is to integrate—*i. e.,* sum up—and to register in commercial units the electrical energy supplied through it.

Ammeters, voltmeters, indicating wattmeters, dynamometers, and the like, will here be considered as "instruments"—not meters—since they merely indicate the amperes, volts and watts, without respect to the time element which is included in the generally accepted commercial units.*

Demand indicators and similar apparatus indicate the maximum load, and will not be considered, since they do not integrate.

Bristol and other curve or chart-drawing instruments, being recording instruments, will not be considered, as they merely record on a disc or strip of paper the passing load for each instant and do not integrate it. The chart from a recording ammeter or wattmeter can be integrated by determining the average amperes and watts for each hour and then taking the sum of such averages.

It is the intention here to consider only integrating meters, and when using the term meter it must be remembered that it is the integrating meter to which reference is made.

METERS MAY BE DIVIDED INTO TWO GENERAL CLASSES, VIZ., AMPERE-HOUR METERS AND WATT-HOUR METERS.

Ampere-Hour Meters.—In the early period of development, meters of the ampere-hour class received the most attention and were most in demand. This was due to their simplicity and consequent low cost, and also to the fact that the watt-hour or energy meters were then practically limited to a single design, that of the motor type; whereas there was a number of principles that could be applied in the design of ampere-hour meters; as, for instance, motor and electrolytic.

Meters of the ampere-hour class designed on the induction principle had an advantage, in many respects, over the electrolytic meters and also over motor-type meters of the watt-hour class. The ampere-hour meters were simple in construction, neat and small in design, easily connected to the circuit, and provision was made for readily adjusting and calibrating them in service. The moving element was light in weight, the meters were free from shunt losses, the first cost was comparatively low and the cost of maintenance was very reasonable. Ampere-hour meters of the chemical type were unsatisfactory, as the consumer could not determine the amount of the consumption, and these meters required too much attention, and the cost of maintenance was too high.

In the use of ampere-hour meters of the induction type a number of vital points must be given due consideration. Meters of this class and type invariably have a low torque, consequently any change in friction materially affects their accuracy, especially on light loads, and frequently the larger capacity meters of this class will not register at all until the load has reached several amperes.

Where the drag on the moving element is produced by the fan-method, the acuracy of such a meter is affected by barometric changes. Inasmuch as ampere-hour meters are not energy meters, it is necessary to assume that the current is furnished at a certain definite voltage. It is not possible for the central station operator always to maintain this assumed voltage, thus it is evident that the ampere-hour class of meters will not register the true amount of energy.

When ampere-hour meters are used on alternating-current circuits, they are suitable only for purely non-inductive loads, and will not give accurate results if connected to circuits supplying motors or other inductive translating devices, as they will record the wattless current.

Some of the early types of ampere-hour meters were calibrated in lamp-hours. The manufacturer or lighting company determined the average current, that is, amperes consumed by the lamps in use (this amount of current for an interval of one hour being called a lamp-hour), and the meters were calibrated accordingly. Other ampere-hour meters were calibrated in watt-hours, the normal voltage of the circuit being taken as the voltage at which the current was consumed. The majority of the ampere-hour meters, however, were calibrated to indicate directly in ampere-hour units. Most of these early types of meters have become obsolete, and only a few are now in use.

Watt-Hour Meters.—It is the general practice of the manufacturers and others to speak of the watt-hour meters simply as wattmeters. This practice is, however, apt to be misleading, and it would be preferable to name them integrating watt-hour meters or watt-hour meters.

A watt-hour is the energy of a watt expended during one hour, and a kilowatt-hour is 1,000 watt-hours. The following is therefore evident:

1000 watts expended for	1	hour	=	1000 × 1,	or	1000 watt-hours.
2000 " " "	0.5	"	=	2000 × 0.5	"	1000 " "
4000 " " "	0.25	"	=	400 × 0.25	"	1000 "
500 " " "	2	"	=	500 × 2	"	1000 " "

Thus a watt-meter may be viewed as a meter that automatically multiplies the passing load in watts by the time and records the product on a dial.

At the present time the majority of the manufacturers are supplying to the general market only watt-hour or energy meters.

The early types of motor meters of the watt-hour class were somewhat crudely constructed, being large and heavy and having many other objectionable features. There was no provision for adjustments or means for compensating for friction. The moving element was very heavy and the accuracy curve was not all that could have been desired. The early meters of this class have become obsolete, and very few are now in service, having been replaced with the more modern types.

Many very marked improvements have been made in the recent watt-hour meters, among which are provisions for adjusting the meters while in service, the reduction in the weight of the moving element, thereby insuring a longer life of the jewel, and consequently more permanent calibration. The shunt losses have also been reduced to about one-third of the former amount, and the general dimensions and weight have been reduced, consequently the meters are more compact and of more pleasing design.

TYPES OF METERS.

The types of meters now manufactured for the American market may be divided as follows:

Type	Designed for	Class
Electrolytic	Direct current	Ampere-hour meter
Mercury	Direct current	Ampere-hour meter
	Direct current	Watt-hour meter
	Alternating current	Watt-hour meter
Commutated	Direct current	Watt-hour meter
Induction	Alternating current	Watt-hour meter

*N. E. L. A., 1909.

THEORY OF INDUCTION WATT-HOUR METERS.

General.—The principle of the induction watt-meter is quite similar to that of a rotating-field induction motor; and, in general, depends upon the production of a torque or turning moment in a movable closed secondary or rotating element by means of a rotating magnetic field; this field being established by the combination of the magnetic fields produced by the series and shunt elements. The interaction between the fields and the opposing fields of the currents induced in the moving element cause the secondary or rotor to turn; its speed being directly proportional to the passing energy. To obtain this speed relation the generally used magnetic brake is employed to provide a retarding torque which is proportional to the speed.

Development.—The early experimenters discovered many of the phenomena embodying the elementary principles upon which the modern induction apparatus has been developed. One of the most important discoveries was that the spinning or revolving of a metallic disc over which was suspended a magnetic needle would tend to rotate the needle in the direction of the rotation of the disc. This effect, first called the magnetism of rotation, is now generally known as Arago's rotation. Similar effects were observed by many experimenters, some of whom also discovered that, by reversing the preceding experiments, rotation of a suspended metallic disc could be produced by rotating a permanent magnet placed directly beneath the disc; the poles of the permanent magnet being arranged so that when the magnet was rotated the magnetic flux passed through the disc and cut it.

Induction Principle.—A non-magnetic, metallic disc suspended so as to be free to rotate, over which is placed a permanent steel magnet, arranged to be independently rotated, is the most simple form of induction motor of which the mind can conceive.

When the permanent magnet is rotated the field or magnetic flux from the magnet cuts the metallic disc, thus inducing eddy currents therein and creating magnetic fields having polarities that oppose the field that originally produced them. It is therefore evident that as the disc is free to rotate it will endeavor to maintain a relative position so that there will be the least cutting of the field of the permanent magnet; that is, the disc will revolve in the same direction as the magnet.

The direction of the induced current in the disc will be at right angles to the direction of rotation and to the direction of the magnetic flux producing it. The polarity established by the eddy currents flowing in the portion of the disc that is just coming under the magnet pole will be the same as the polarity of the pole inducing it, thus producing a relative repulsion or thrusting effect. The polarity of the eddy currents in the portion of the disc over which the magnet has just passed will be of opposite polarity to the pole producing it, consequently an attraction exists that also tends to retard the relative motion. The disc is therefore caused to rotate in the direction of the rotating magnet. The mode of operation of this simple form of rotating-field induction motor is quite similar to the method of operation of an alternating-current induction meter.

Shifting Magnetic Field.—In the first form of induction motor made, rotation of a non-magnetic metallic disc was produced by means of four fixed electromagnets, energized in such a manner as to cause the magnetism to shift, progressively, between the poles, thus inducing eddy currents in the disc, and by the reaction the disc was caused to rotate in the direction of the progression of the magnetic poles. In this arrangement the electromagnets were energized with direct current, and the shifting of the poles was accomplished by means of a suitably arranged commutating device. By this method a shifting magnetic field was obtained, which is essential to produce rotation of the moving element.

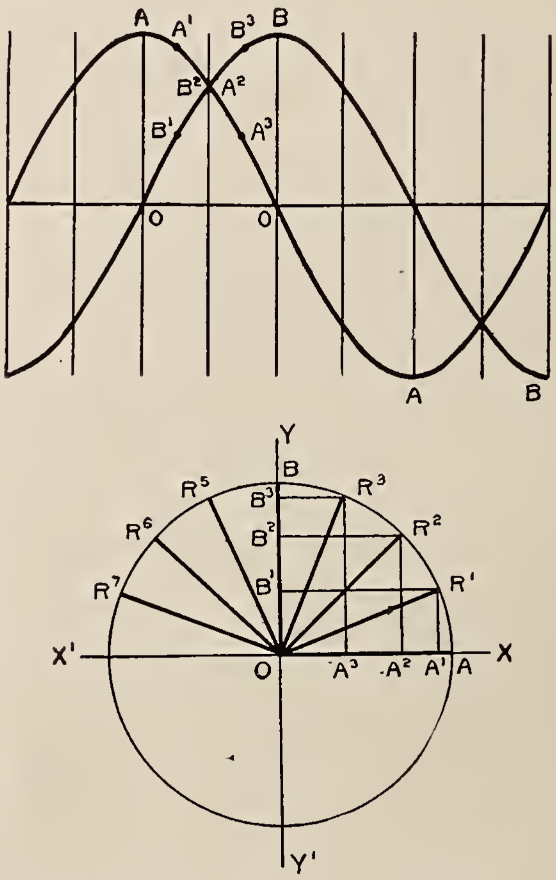


FIG. I.—TWO ALTERNATING CURRENTS, IN QUADRATURE, SHOWN IN WAVE FORM, AND THE RESULTANT ROTATING FIELD PRODUCED BY COMBINING THE FIELDS OF THE TWO CURRENTS

Rotating Magnetic Field.—The theorem that a true rotating magnetic field can be produced by combining the magnetic fields of two alternating currents, of exactly the same frequency and amplitude, which differ in phase by 90 degrees—or are in quadrature—will be considered graphically.

Referring to the diagram in Fig. 1, the curves A and B represent two alternating currents differing in phase a quarter period, or 90 degrees. The magnetic field produced by the current A may be represented as traveling along the line X-X', rising toward X and falling toward X'. Likewise the magnetic field produced by the current B may be represented as traveling along the line Y-Y', rising along the line toward Y and falling toward Y'. The magnetic fields produced have the same period and amplitude, but are constantly changing in strength and have a 90-degree phase relation.

It is evident that when the magnetic field produced by A is at a maximum B is zero and produces no field, therefore the resultant field lies along the line OX, having a strength as represented by the line OA. Now, as the field of A decreases, represented by OA^1, the strength of the field of B gradually increases, as represented by OB^1 along the line of OY. By combining these two forces or magnetic fields, the resultant field OR^1 is produced. It is also evident that when the field of A has decreased to A^2 the field of B has increased to B^2, and by combining these two fields the resultant field OR^2 is produced. As the field of A decreases further to the point of A^3, the field of B will increase to the point B^3, producing the resultant field OR^3. Likewise, when the field of A has become zero, the field of B has its maximum value and the resultant field is represented by OB along the line OY.

It is clear that the resultant magnetic field has gradually been shifting or rotating in a counter-clockwise direction, and if the resultant field be plotted for the remainder of the cycle it will be found to rotate uniformly around the point O. Thus the combination of two magnetic fields that vary in the proper manner will produce a constantly rotating magnetic field, the magnitude of which will be the same throughout the cycle.

Production of a Rotating Magnetic Field by a Two-Phase Current and Its Application to Induction Motors.—As shown, a rotating magnetic field can be produced by two alternating currents, differing in phase relation by 90 degrees. The rotating field thus obtained may be utilized to cause the rotation of non-magnetic, metallic

discs and cylinders by means of the eddy currents established in them. The production of rotation in this manner is the real foundation from which induction motors and induction meters have been developed, this being the principle that was employed in the first form of alternating-current induction motor produced.

Two alternating currents having a 90-degree phase relation may be represented in wave form as shown in Fig. 2 *a*. The curve *C* represents the

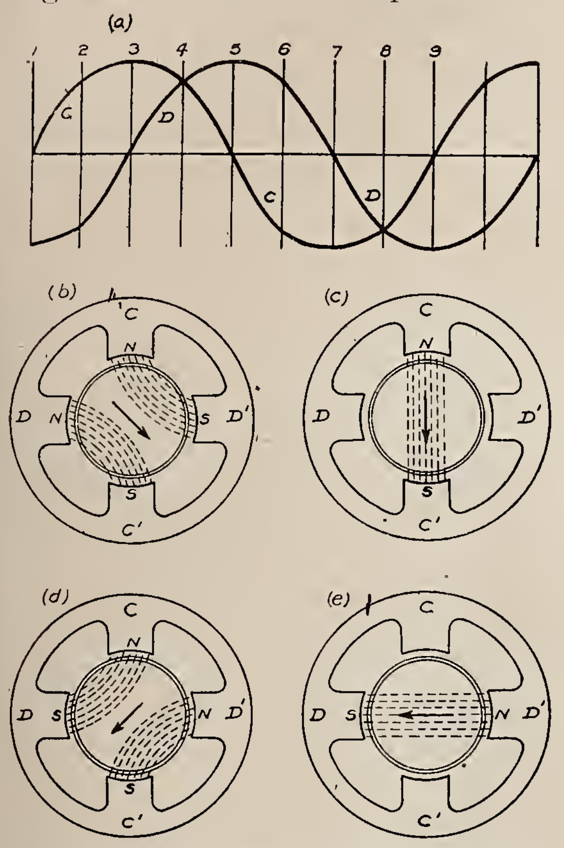


Fig. 2—Direction of the magnetic flux, at given instances during a half cycle, produced by applying two alternating currents having a 90-degree displacement to a four-pole motor

magnetic field produced by one current, and the curve *D* represents the magnetic field produced by the current in quadrature. The ordinates marked 1 to 9, inclusive, divide a complete cycle, so that the magnitude of the magnetic fields produced by the two currents may be considered at different instants.

The application of two currents, as stated, to an induction motor having four poles symmetrically arranged around a closed circuit metallic armature is shown in Fig. 2, *b*, *c*, *d* and *e*. These diagrams also indicate the manner in which the resultant magnetic field is developed and rotates.

Assume that the coils of the motor on the poles marked *C* and *C'*, which are diametrically opposite, are connected across the circuit, of which *C* is the current curve, and that the coils on the poles marked *D* and *D'*, which are also diametrically opposite, are connected to the circuit, giving the curve *D*.

The direction of the magnetic fields established at the instant represented where ordinate 2 intersects the curves will be *N-S* from pole *C* to *D'* and from *D* to *C'* as shown in *b*.

At the instant represented by ordinate 3 the field produced by the current *C* will be at its maximum and have a direction *N-S* from pole *C* to *C'*, as shown in *c*, while at the same instant current *D* is crossing the zero line, changing from a negative to a positive value and hence producing no field.

At the instant represented where ordinate 4 intersects the curves, both currents have positive values and the magnetic field produced as shown in *d* is *N-S* from pole *C* to *D* and from pole *D'* to *C'*.

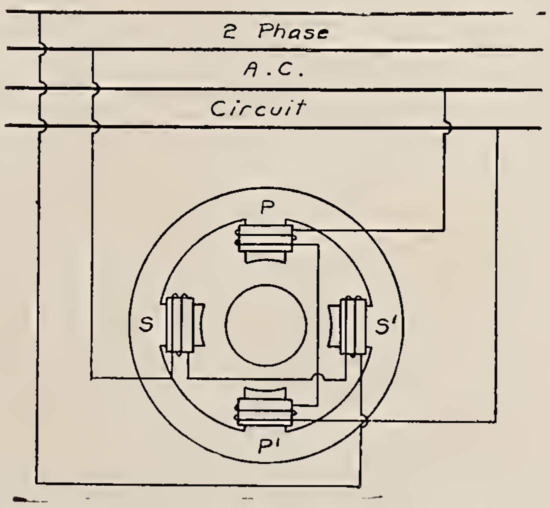


Fig. 3—Application of a two-phase alternating current to produce a rotating magnetic field

At the instant represented where ordinate 5 intersects the curves, the field produced by current *D* will have a maximum value; at the same instant current *C* will be crossing the zero line, changing from a positive to a negative value and will therefore produce no field. The direction of the field produced by current *D* is *N-S* from *D'* to *D*, as shown in *e*.

If the same method is employed to follow the direction and relation of the fields at the different instants, throughout a complete cycle, it will be noted that the magnetic poles progress or shift and that a traveling field is established which rotates in a clockwise direction.

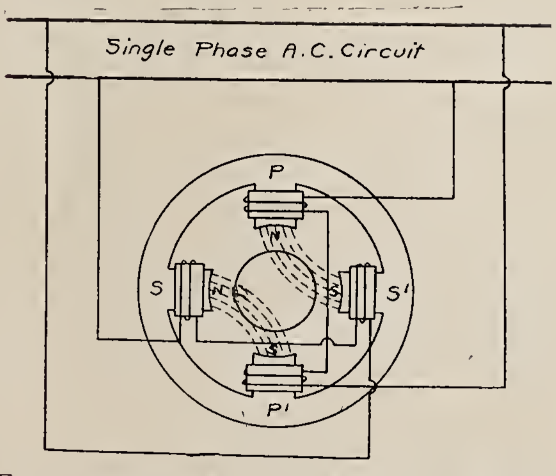


Fig. 4.—Fields of a single-phase current, alternating between the poles of an induction motor

Magnetic Fields Established by a Single-Phase Alternating Current.—It has been shown that a rotating magnetic field may easily be established by two alternating currents having a 90-degree phase difference, when the field coils are connected independently to different phases, as shown in Fig. 3, but it is important to consider the results that will be obtained if the fields of a similarly constructed motor are connected to a single-phase circuit.

Fig. 4 shows the fields of an induction motor with the diametrically opposite poles connected in series, the two pairs *P-P'* and *S-S'* being connected in multiple to a single-phase circuit. As the currents in the two circuits have the same phase relation, the magnetic fields produced are also in phase and will rise and fall simultaneously in both circuits, reversing in direction with each reversal of the alternating current. The magnetic fields produced will alternate between the poles *P* and *S'* and *S* and *P'*, as shown by the dotted lines in the diagram, therefore no rotating field traveling from one set of poles to the other will be established.

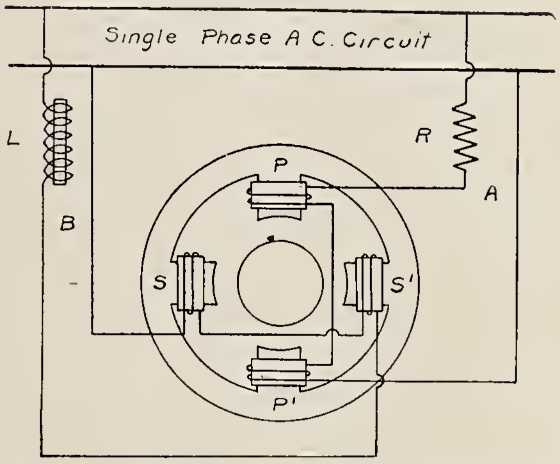


Fig. 5—Method of applying a single-phase current to a four-pole induction motor so as to produce a rotating field

Method of Producing a Rotating Field with a Single-Phase Alternating Current.—It has been clearly demonstrated that a rotating magnetic field can be established by a combination of fields produced by alternating currents having two phases, and this is the principle that is so generally applied in alternating-current multiphase induction motors. However, in the design of alternating-current induction meters it is not necessary to use a multiphase circuit, as a simple method may be employed to produce a rotating field with a single-phase current.

In this method two independent branch circuits are necessary, both being connected in parallel to the mains of a single-phase circuit, as shown in Fig. 5. A non-inductive resistance *R*, is connected in series with branch circuits *A*, causing practically no phase displacement. A coil, *L*,

having a very high inductance and a small resistance, is connected in series with branch circuit *B*. This produces a phase displacement between the currents in the branch circuits that approaches 90 degrees sufficiently to produce a rotating magnetic field. It is this principle that is taken advantage of in the design of all alternating-current induction wattmeters.

Split-Phase Method.—The split-phase method of producing a rotating field is sometimes referred to when describing the principles of operation of induction wattmeters. This method, however, was originally suggested as a means of starting two-phase induction motors on a single-phase alternating-current circuit by employing an arrangement for splitting the phase. Two branch circuits are used to connect the field coils to the mains. An inductance is connected in series in one branch and a resistance is connected in the other branch; the arrangement being quite similar to that previously described.

A split-phase device is required which consists of an apparatus to switch the inductance and resistance in and out of circuit. With this arrangement a rotating field is established that produces sufficient torque to start the motor, after which the fields are connected direct to the main circuit.

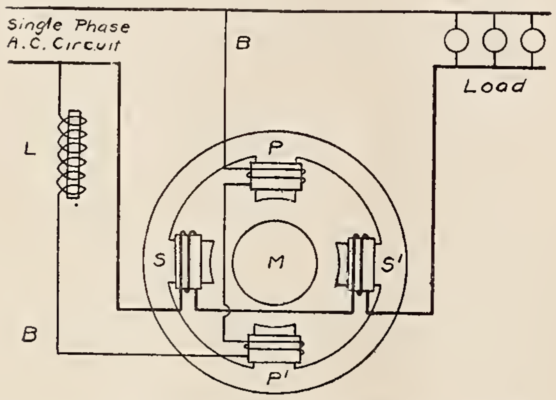


Fig. 6—THE SPLIT-PHASE METHOD OF PRODUCING A ROTATING FIELD APPLIED TO INDUCTION METERS

Split-Phase Applied to Induction Meters.—The method in which the foregoing principles are directly applied in the design of an induction meter is represented in Fig. 6. It will be noted that a single-phase alternating-current circuit is employed, to which the field coils are connected in a special manner as described.

The coils *P* and *P'*, which are wound with small wire, and an inductance coil *L*, are connected in series, forming the branch circuit *B* which is connected in multiple across the main circuit. The strength of the magnetic field produced by the field coils *P* and *P'* will necessarily vary with the e.m.f. of the main circuit, and the field will have a large phase displacement due to the inductance coil, the function of which is to lag the current in the branch circuit as near 90 degrees as possible.

The field coils on poles *S* and *S'* are wound with large wire and are connected in series with the main circuit and therefore with the load. In this arrangement a non-inductive load or translating device is used in place of the non-inductive resistance *R* previously mentioned. The strength of the magnetic field produced by poles *S* and *S'* will be directly proportional to and increase or decrease with the load being dissipated. Consequently there will be no magnetic flux when there is no current passing through the series or main circuit.

It is evident that as the current in branch circuit *B* is lagged so that a phase displacement occurs which approaches 90 degrees and as the series load is non-inductive, producing practically no phase displacement of the field in poles *D* and *S'*, the combination of the two fields will produce a resultant rotating magnetic field and cause the rotor *M* to turn in the same direction as the progression of the field.

The arrangement of the poles *P* and *P'*, *S* and *S'* and rotor *M* as just described, and as shown in Fig. 6, has the appearance of the design generally employed in the construction of alternating-current induction motors, and it is obvious that in the design of an induction meter for use in service the arrangement of the magnetic poles with respect to the rotor or moving element would necessarily be somewhat different and would vary in the different designs of induction meters; nevertheless, the principle involved is essentially the same.

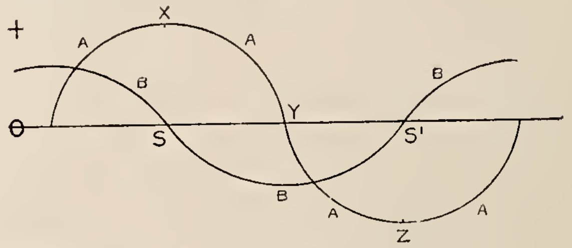


Fig. 7—CURRENT AND REACTANCE E. M. F. WAVES

Induction Meter Principles.—An induction meter is practically a form of motor, the fields of which are produced by the application of a split-phase principle to an alternating-current single-phase circuit. The magnetic poles are so arranged that the fields combine and act on a short-circuited movable armature. By the reaction of the eddy currents thus developed and the rotating magnetic field established, a rotation of the moving element is produced. The addition of a suitable retarding device completes the electrical part of this meter. With this construction the number of revolutions of the moving element is proportional to the energy units dissipated, which is a function of an integrating meter.

Inductive Reactance E.M.F. Component.—A conductor carrying a current is surrounded with a magnetic field, and any change in the current will produce a corresponding change in the field. If the current is alternating, the magnetic field will change with each alternation, consequently the field will be continually destroyed and re-established.

An alternating current is represented in wave form in Fig. 7, in which curve *A* represents the power or load e.m.f. If the portion of the curve above the line *O* is considered as having a positive value and that portion below the line as having a negative value, the magnetic field is destroyed and re-established at the point *Y*, when the power e.m.f. is changing from a positive to a negative value.

When a field changes or collapses, the magnetic lines cut the conductor carrying the current and establish an e.m.f. in that conductor; that is, the reactance e.m.f.. It will be noted that the magnetic field is changing at its greatest rate at the point *Y*, therefore the reactance e.m.f. will have its maximum value at that instant, as shown by curve *B*.

At the instant the power e.m.f. has a maximum positive or maximum negative value, represented by points *X* and *Z* respectively, there is no change in the magnetic field, consequently the field does not cut the conductor. The reactance e.m.f. is therefore zero at those instants, and the curve is shown as crossing the zero line at the points marked *S* and *S'*.

It is evident that the reactance e.m.f. of any circuit is always 90 degrees with relation to the power, or load e.m.f.

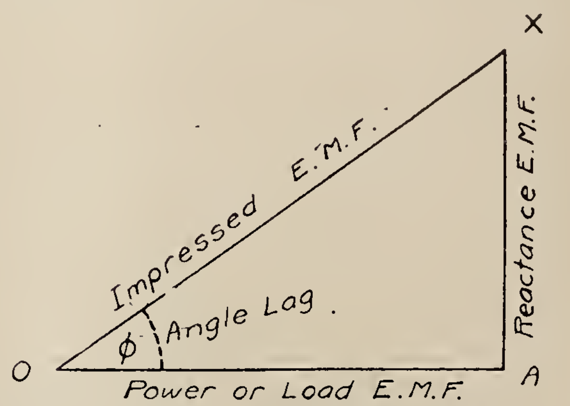


Fig. 8—E. M. F. VECTORS OF AN ALTERNATING CURRENT CIRCUIT

Relation of Reactance, Power and Impressed Electromotive Forces.—A diagram of forces may be plotted to represent the relation of the various e.m.f's. as shown in Fig. 8.

The reactance e.m.f. component is plotted at right angles to or 90 degrees from the power e.m.f.

The power or load e.m.f. is the e.m.f. component that is useful in doing work, and is always in phase with the current in the circuit.

The impressed e.m.f. is plotted as the hypothenuse of the triangle, and is the e.m.f. required to be applied to the circuit to overcome the reactance e.m.f. and to give a power e.m.f. equal to the component shown.

The sign Φ represents the angle of lag between the impressed e.m.f. and the power or load e.m.f.

Power calculations and Formulæ.—The power in the circuit, which is equal to the product of the power e.m.f. and the current, may be easily determined when the reactance component is zero, for then the impressed e.m.f., which is a measureable quantity, is in phase with the power e.m.f. When a reactance component exists, the impressed e.m.f. will not be in phase with the power e.m.f. As the current in phase with the power e.m.f. and the impressed e.m.f. are the measurable quantities, the angle of lag between the impressed e.m.f. and the power e.m.f. or current must be taken into consideration.

In determining the true power in the circuit, the factors that enter into the calculation are:

W=The wattage or power.
E =The impressed e.m.f.
I =The current in the circuit.
Φ =The angle of lag between the impressed e.m.f. and current.

The formula is:

$W=E\ I$ cosine Φ
When $\Phi=0$
Then cosine $\Phi=1$
Therefore $W=E\ I$

The true power and the apparent power are equal, and the reactance component equals zero, as the impressed and power e.m.f. are in phase.

When $\Phi=90$ degrees
Then cosine $\Phi=0$
Therefore $W=0$.

The impressed e.m.f. and the power e.m.f. are then at right angles, and

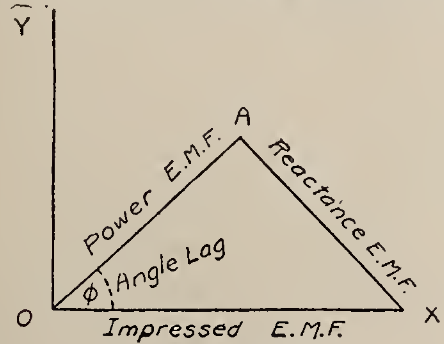


Fig. 9—ALTERNATING-CURRENT E. M. F. VECTOR DIAGRAM

the reactance component is equal and opposite to the impressed e.m.f.

It is evident that the power in the circuit is a function of the angle of lag between the impressed e.m.f. and the power e.m.f. or current, and when the displacement is 90 degrees the power becomes zero.

The Relation of Torque and Power to the Cosine of the Angle of Lag.—The torque of a meter must become zero when the power in the circuit is zero, and as it has been proven that the power in the circuit is a function of the cosine of the angle of the lag and that the power becomes zero when the angle of lag is 90 degrees, therefore the torque must be proportional to the cosine of the angle of lag.

It follows that, when the field of the shunt coil lags 90 degrees behind the impressed e.m.f. and the current in the series coils lags 90 degrees, there is a condition of no power in the circuit, and no torque to produce rotation exists.

When a meter operates on a non-inductive circuit, the reactance e.m.f. component is zero and the power e.m.f. component coincides with the impressed e.m.f. The fields produced by the series coils and shunt circuit are displaced 90 degrees and consequently produce maximum torque for minimum apparent power.

In Fig. 9 the field of the shunt circuit is represented by the position of the line OY and the impressed e.m.f. by the line OX, the phase relation being 90 degrees.

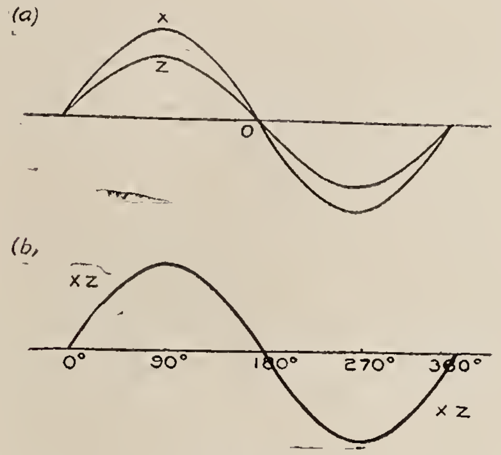


Fig. 10

(*a*) Curves of Magnetic Fields for Synchronous Alternating Currents of *Different* Value.

(*b*) Curves of Magnetic Fields for Synchronous Alternating Currents of the *Same* Value.

When a meter is operated on a circuit containing inductance, the phase position of the power or load e.m.f. depends upon the reactance e.m.f. component.

With an impressed e.m.f. of a given value, the greater the reactance e.m.f. component, the greater the angle of lag and the smaller the power or load e.m.f. component. When the magnitude of the reactance component is sufficient to cause the power e.m.f. component to reach the 90-degree position, the field produced by the series coils and by the shunt circuit will be in phase and therefore will produce no torque or rotation of the moving element.

Phase Relation of Component Fields to Produce Maximum Torque.—A maximum torque or rotating effect is obtained when the series and shunt component magnetic fields bear a certain definite phase relation with each other, as described.

Referring to Figure 10, diagram *a*, curve X represents the magnetic field produced by a single-phase alternating current and curve Z represents the field produced by a current from the same source. The field X is shown as having a greater strength than field Z and its curve therefore has a greater maximum value, but it is evident that when both fields have the same maximum value the curves representing them will be identical and the points will coincide, so that the curves will appear as a single curve as shown in diagram *b*.

It has been previously shown that magnetic fields produced by single-phase currents that are in phase will not combine and establish a resultant rotating field, but will simply alternate between the field poles. Hence, a torque to cause rotation of an armature will not exist.

By reversing the connections of the circuit that produces the magnetic field Z, the polarity of the field will be reversed with respect to field X. The field Z will then have a maximum

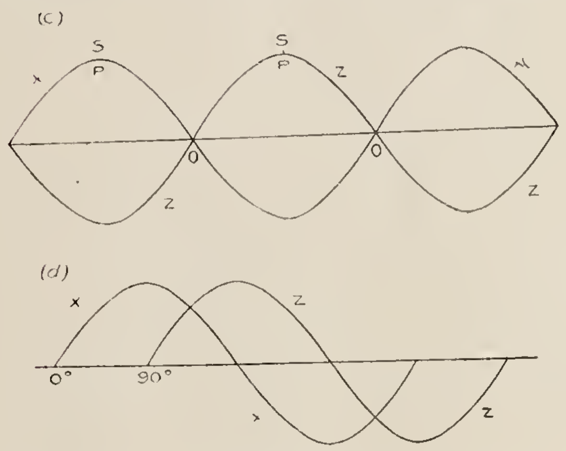


Fig. 11

(*c*) Curves of the Magnetic Fields of Two Equal Alternating Currents in *Opposition*.

(*d*) Curves of the Magnetic Fields of Two Equal Alternating Currents in *Quadrature*.

negative value when the field X has a maximum positive value; both fields reaching the zero position O at the same instant. As the fields are equal and in opposition, the result will be zero flux, consequently there will be no torque or rotating effort.

When the magnetic field of Z is reversed what really takes place is that the curve Z, Fig. 11, diagram *c*, has shifted 180 degrees; that is, the point P is moved from the position S to S' and no torque results.

It has been shown that there are two positions exactly 180 degrees apart which produce no torque, and it has been demonstrated that when the currents producing the flux are not in phase a torque exists; it is ob-

vious, therefore, that there must be some intermediate position between zero and 180 degrees that will produce maximum torque. It might be assumed that this point is midway between these extremes or the 90-degree position shown in diagram *d,* and such is the case, for when the magnetic fields are in quadrature they have a maximum average value, and consequently produce maximum torque.

Magnetic Fields Established by the Current and Potential Circuits.—The magnetic fields that produce rotation of the movable member are established by the series coils and potential coils; these fields being proportional to the main current and to the pressure of the circuit respectively.

On non-inductive loads the series coils connected in the main circuit produce a field that is practically in phase with the impressed e.m.f. The field of the potential coils, which are connected across the main circuit, is produced by the current, which is lagging in this circuit; therefore the field is displaced about 90 degrees with respect to the field of the current circuit.

It is impossible to lag the current in the potential circuit exactly 90 degrees by means of an impedance coil, on account of the energy expended in overcoming the electrical losses, therefore the condition of maximum torque cannot be obtained by the split-phase method unless a special means of phase compensation is provided.

It is not essential that a phase displacement of exactly 90 degrees should exist between the magnetic flux of the current and potential circuits when the load to be metered is non-inductive, as the current and voltage are then in phase, and under this condition a meter with fields not in perfect quadrature will register with accuracy the energy consumed in the circuit.

When the load to be metered is inductive, a phase difference occurs between the current and voltage and the power in the circuit is then equal to the product of the current and voltage multiplied by the cosine of the angle of lag. The driving torque of a meter will vary with these factors, so that its speed will represent the power in the circuit only when there is an exact 90-degree displacement of the shunt flux from the impressed e.m.f. Therefore phase compensation to secure this relation is necessary, otherwise the meter will register inaccurately on an inductive load.

Methods of Lagging or Phase Compensation.—Various methods have been devised to secure a condition where the magnetic flux produced in the potential circuit is in exact quadrature with the e.m.f.

One of the methods available is to lead the flux of the current coils by dividing the main current circuit in two parts; one circuit having practically no inductance and the other being highly inductive and connected in reverse relation to the first. By adjusting the two coils a resultant magnetic field is produced by the series coils which leads the field of the pressure circuit by an angle of 90 degrees.

Another means employed to obtain the proper phase relation is to arrange in parallel a non-inductive and an inductive resistance and to connect an impedance coil in series with these resistances; the whole being connected across the main circuit. The impedance coil alone will lag the current nearly 90 degrees, but by dividing the current in the impedance coil by means of resistances, a resultant shunt flux is produced which has a 90-degree phase displacement with respect to the impressed e.m.f.

While the two methods described are used in European meters, they are not at present used by American manufacturers.

The generally used method consists of connecting an impedance coil, either alone or in series with an additional coil, across the pressure circuit so as to produce an initial phase displacement as near 90 degrees as possible.

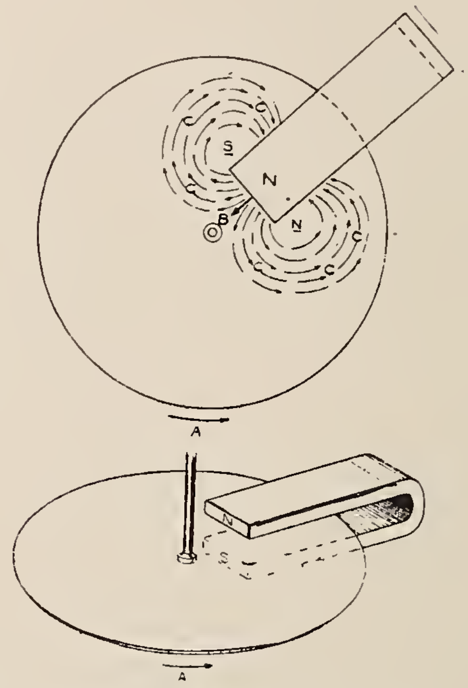


Fig. 12—EDDY CURRENTS INDUCED IN A DISC ROTATING IN A MAGNETIC FIELD

Short-circuited secondary windings or coils are arranged in such relation with respect to the main shunt circuit that the shunt winding acts as a primary to the secondary coil. The magnetic field of the shunt circuit produces currents and consequent fields in the secondary coil which combine to produce a field having an additional lag. This may be adjusted to have the proper 90-degree phase relation.

Magnetic Brake.—Wattmeters of the motor type are provided with a magnetic brake, which is necessary in order to obtain a speed directly proportional to the power.

When a conductor that is part of a closed circuit is moved across a magnetic field, an e.m.f. is generated in it that is proportional to the speed. A current will flow that is proportional to the e.m.f. and to the resistance. If the resistance be kept constant, the current will be proportional to the e.m.f. generated and is therefore directly proportional to the speed.

In the magnetic brake a constant field is supplied by a permanent magnet. Between the magnet poles revolves a copper or aluminum disc or cylinder which is fixed on the shaft. The conductor is therefore directly under the poles, and the disc provides a closed circuit of constant resistance.

The action may best be understood by referring to Fig. 12. The direction of the magnetic flux is downward from *N* to *S,* cutting the disc which rotates, as shown by the arrow *A.* This causes currents to be generated in the disc having a direction shown by the arrow *B.* These currents divide and return through the part of the disc where no current is being generated, as shown by arrow *C.*

The eddy currents generated produce poles proportional to their strength, as shown by N and S on the upper side, and the corresponding poles (not shown) are established on the under side of the disc. Pole *N* repels N and attracts S, and *S* correspondingly repels and attracts the poles not shown. As both of these attractions and repulsions oppose the motion of the disc, a magnet placed in this manner embracing the non-magnetic disc will create a drag proportional to the speed of the disc.

Meters are provided with a magnetic brake, consisting of a permanent magnet or magnets, and a copper or aluminum rotor which revolves between the magnet poles.

The speed of the rotor is generally regulated by adjusting the magnets in or out from the center of the disc; or by adjusting them to embrace more or less of the movable member, thus changing the amount of flux cut. Another method of speed regulation is to provide the magnets with an adjustable iron armature placed over the poles, so as to divert or shunt around the rotor more or less of the magnetic flux.

Iron shields are sometimes provided to protect the magnets from abnormal magnetic flux, which is generally caused by short-circuits on the line.

(To Be Continued)

Investigating the Cause of Breakage of High Tension Glass Insulators*

A few years ago an electric railway company in the Central States built a 30,000-volt transmission line about as shown in the accompanying sketch. Sections A-B-C-F were six wires, the balance three wires. The poles were spaced about 100 ft., and, allowing for double-armed poles, there were approximately 31,000 high-potential insulators on the 112 miles of transmission line. The 10-mile section B-C was first constructed, and in this section about 4000 glass insulators were used, of a type which will be designated as "A." Contracts for the balance of the line were let later, and for the remaining 102 miles approximately 27,000 glass insulators of a type "B" were bought. The two insulators were of somewhat different designs, but about the same size and weight:

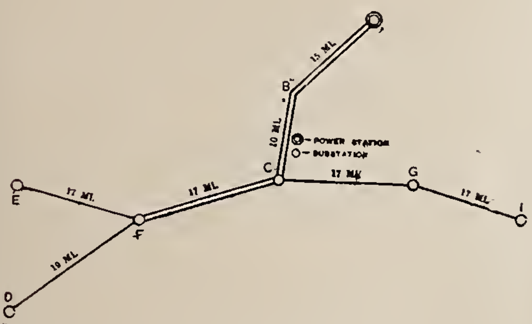


DIAGRAM OF HIGH-TENSION TRANSMISSION LINE.

	Insulator "A"	Insulator "B"
Outside diameter........	7 in.	7 ½ in.
Total arcing distance, tie wire to pin...........	6⅝ in.	6 15/16 in.
Total surface leakage distance, tie wire to pin..	11⅜ in.	10 ¼ in.
Distance on surface, tie wire to edge of skirt....	4 in.	3 ¼ in.
Arcing distance, edge of skirt to pin...........	2⅝ in.	3 11/16 in.
Surface leakage distance, edge of skirt to pin....	7⅜ in.	7 in.
Weight................	4 lb. 12 oz.	4 lb. 8 oz.

Manufacturer "A" refused to make any electrical guarantees whatever. Manufacturer "B" guaranteed his insulators to withstand certain electrical tests, such as the salt water puncture test at 60,000 volts, a test between a wire tied to the neck of the insulator in the usual manner and the leadfoil-covered surface of the pin upon which the insulator was mounted at 90,000 volts, etc.

Insulator "B" was finally chosen for the 102 miles remaining to be constructed for the following reasons: Willingness of manufacturer to make electrical guarantees; similarity in size and weight of the two insulators. "B" having the advantage as to greater arcing distance, which was considered important; and a much lower bid price on the "B" type insulator. The contract for 27,000 insulators furnished by manufacturer "B" specified the type and design of the insulator by its catalog or trade designation, and also specified that each insulator furnished should be capable of withstanding the electrical tests before mentioned. The contractor guaranteed the fulfilment of these specifications, and also that "except where otherwise specified, material shall be of the first quality and workmanship of the best."

The transmission line having been built and operation started with a line voltage of approximately 30,000, the "B" type insulators began to break down. From the first accurate records were kept, showing in each case of breakdown the date, hour, length of time during which operation was interrupted, weather and temperature conditions, etc. Although there was no absolute uniformity, the breakages occurred most frequently in rainy weather. The following statement shows the total number of failures, by months, during the period in which the "B" type insulators were in service:

October (half month)	28	August	18
November	33	September	28
December	24	October	16
January	66	November	59
February	60	December	102
March	63	January	51
April	5	February	40
May	6	March (nine days)	9
June	24		
July	17	Total	649

This list includes only the "B" type insulators, of which the total number in service was about 27,000. During this period but one "A" type insulator failed in the same service, of a total of 4000 in use.

About 100 miles of electric railway was dependent upon this transmission line for power. Four of the six substations contained regulating storage batteries, which were capable of carrying the ordinary total load on those substations for 20 to 30 min. Failure of power supply for even five minutes was sufficient to interfere with schedules, while a failure lasting 20 min. or more meant their complete demoralization. If the defective insulator was in sections A-B-C-F, where the transmission line was in duplicate, it was sometimes possible to operate all substations through the remaining one of the parallel transmission lines. Often, however, both circuits would be affected; in this case, or if the trouble was in one of the other sections with but a single transmission line, all substations beyond the defective section were without power until the defective insulator was located and replaced.

The company repeatedly called upon the manufacturer to replace the "B" type insulators. At first this was met by a policy of delay, the manufacturer holding that a few defective insulators were to be expected in so large a lot. Later he refused to replace the insulators, and the company, declining to pay for them, replaced them with "A" type insulators. Since that time the operation of the transmission line has been entirely satisfactory, and the number of insulator breakages has been normally low—a total of about 20 out of some 31,000 insulators in service for four years.

Following the traction company's refusal to pay for the "B" type insulators, the manufacturer sued for payment. His claim was that a certain type of insulator had been specified and that type furnished, also that such tests as were specified in the contract had been made and successfully met. These claims the traction company did not deny, but raised the point that the guarantee as to workmanship and material had not been met, in that the insulators had been improperly, imperfectly or unevenly annealed. The effect of poor annealing was shown to decrease the specific resistance of glass, thus allowing more leakage current to pass through to the pin and abnormally heat the insulator; also to set up uneven and abnormal stresses in the glass, thus rendering it less able to withstand the mechanical strains due to expansion and contraction. This argument was strengthened by these facts: That insulators broke after current was applied to the line; that more insulators broke during rainy than during dry weather, and that the "A" type insulators on the same transmission line suffered practically no breakage during the time that the "B" type was breaking constantly.

Tests by polarized light proved type "B," although of the same chemical composition, was subjected to stresses caused by improper annealing, while in type "A" there was an almost entire absence of stresses. In carrying out the tests each insulator was so mounted that when it was rotated about its pin axis the same thickness of glass skirt was always presented between the polarizer and the analyzer, which previously had been arranged so as to allow no light to pass. Stresses in the insulator were indicated by the varying intensity of light and by color changes. The insulators showing stresses had been poorly annealed. Under service conditions they became heated on account of conductive leakage and were destroyed.

* Abstract of paper by Albert S. Richey, E. E., and Frederick Bonnet, Jr., Ph. D., read before the Worcester Polytechnic Institute chapter of the Sigma Xi Society.

Some Features of Condenser and Cooling Tower Design and Operation

M. R. BUMP

It would be manifestly impossible to treat the general subject of condenser and cooling tower design in a comprehensive way within the limited time and space afforded this paper. It has therefore been the intention to treat briefly certain points in design and operation that are of greatest importance.*

The fundamental principle of design and operation of steam condensers is to secure a maximum transfer of heat from steam to water at a minimum of expense for fixed charges; that is, minimum first cost plus operating expenses. The choice of this apparatus depends in greatest measure upon the vacuum obtainable under different atmospheric and weather conditions, and when cooling towers are to be used in the design of apparatus allowance must be made for these conditions and apparatus selected which averages best under all conditions.

The cost of pumping the circulating water depends directly upon the amount of heat imparted to each pound of water in the condenser. Therefore, for a minimum of pumping cost, the water should leave the condenser exactly at the temperature of the steam entering the condenser, for in this case each pound of water carries from the condenser the maximum possible amount of heat and the amount of water required is therefore reduced to a minimum. In practical design, therefore, the condenser should be laid out with a view of obtaining this result as nearly as practical conditions will permit. In the surface type condenser, where the heat is transferred through metallic tubes, it is necessary to allow for a certain differential of temperature between the steam and water, and the amount of heat transferred is directly proportional to the differential temperature allowed. If the differential temperature is 5 degrees the surface required will be twice as great as in a case where 10 degrees differential temperature is allowed. The selection of proper amount of surface for any given location may be determined upon the basis of balancing fixed charges on aditional surface against fixed charges and operating expenses of pumping apparatus. As the amount of surface is increased the cost will increase in definite proportion, while the differential temperature required will decrease. The decrease in differential temperature permits of a reduction in the quantity of water to be pumped, and therefore reduces both the size and first cost of the pumps and also the power required to operate the pumps.

The problem is a special one for each installation and should be so considered.

With the jet condenser it should be possible to reduce the differential temperature to a very few degrees, yet it is more common to find the difference greater than in the surface condenser. It is common to see a jet condenser taking water at 75 degrees and discharging at or below 90 degrees when the temperature of the steam is at least 110 degrees. Under this condition the discharge water should be raised to at least 105 degrees, in which case just half of the amount used would be required. The greatest inherent advantage of the jet condenser is wasted by operating in that manner. The writer has seen tests on jet condensers where the differential temperature between entering steam and escaping water was less than two degrees over a wide range in load. When operating on a fluctuating load it may be advisable to allow a somewhat great differential temperature, but there seems to be no good reason why greater than five degrees differential should ever be allowed in a properly designed condenser. The poor results ordinarily reported are due in large measure to carelessness on the part of the engineer, who simply starts the pump and then lets it run at a constant speed.

In selecting a condenser for any given location, the consideration of weather and climatic conditions, of quantity temperature and quality of cooling water, at all times of the year, the variation in steam results on the unit for varying vacua, and the load conditions of the unit to be operated, are all of importance. The question of floor space has an effect upon the size and cost of buildings, and the ground space is often a most important item where ground is very valuable, as in the large cities.

The weather and climatic conditions are particularly important where cooling towers are to be used, as will be discussed later. The consideration of the water supply is of greatest importance. The quality of the water must be carefully considered. If the water is inclined to scale or to deposit solids when heated, the jet condenser is better suited to its use. If, on the other hand, it does not give trouble from this source at the temperatures employed in condensers but does cause scaling or pitting in the boilers, it is a distinct advantage to use a surface condenser and save the condensation for use in the boilers. In this connection, however, it is interesting to note that if the water being used over and over again is not allowed to come in contact with the air, there is a chance for it to become a very pure distilled water, which would very rapidly eat out iron pipe and would attack the iron in the boilers if it were still very free from all impurities when it entered the boilers. It is a well-known fact that pure distilled water will attack more or less any metal, and has an especially harmful effect on iron and steel. Under ordinary conditions, where the water is discharged into an open pump and then pumped into the heater, very little trouble should be occasioned from this source.

The temperature and quantity of water available are important factors. Where the quantity is at all limited it is desirable that the condenser should be designed with a view to imparting to each pound of water the greatest possible amount of heat. The maximum temperature of the water is the most important factor in determining the size of pumps. Where condensers draw their water supply from sources in which the temperature runs very high during summer months it is again very important to impart the greatest possible amount of heat to each pound of water in order to avoid the necessity for installing and operating an excessively large pumping installation. Having given the maximum temperature of the water, it is a matter of considerable work to figure out the best installation. It is often necessary to operate at lower vacua during summer months, and it is often found that many plants do operate on lower vacua than would be necessary if the condensers were properly designed and operated. In order to determine the size and best operating conditions the effect of a reduced vacuum on the steam results of the unit during those weeks or months when the temperature of water is high must be considered.

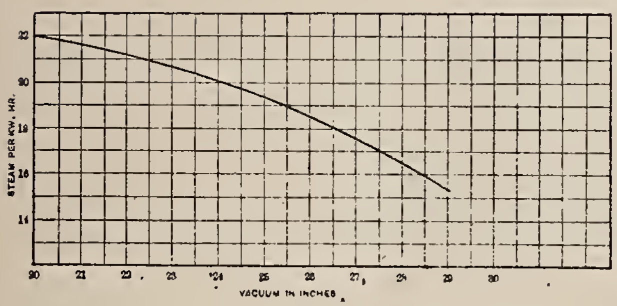
* N. E. L. A., 1909.

The accompanying water-rate curve (Fig. 1) shows the effect of reduction of vacuum upon the economy of a standard steam turbine of 1000-kw. capacity, with 175 lb. steam and 100 degrees superheat.

These data are also summarized as follows:

Vacuum, Inches	Steam per Hour at Full Rated Load, Pounds	Increase Over Consumption on 29-Inch Vacuum	Increase, Per Cent	Approx. Temperature Exhaust Steam, Degrees
29	15,350	....	.....	77
28	16,550	1200	7.8	100
27	17,500	2150	14	116
26	18,550	3200	20.8	124
25	19,350	4000	26	132
24	20,000	4650	30.3	140
23	20,600	5250	34.2	146
22	21,100	5750	37.5	151
21	21.600	6250	40.8	157

Allowing for the differential temperatures required in condenser and tower and for the temperature of the water, the amount of water required for any given vacuum over that of the next lesser vacuum can be determined and the benefits compared with the costs of obtaining same.



It is often possible to effect a very material saving in cost and size of condensers by allowing for a reduced vacuum when the temperature of the water is high. It becomes then a problem of balancing the added cost of fuel, and the like, against the fixed and operating charges on the condensing equipment to determine the most economical installation. If the water rate of the unit is carefully determined by test or can be accurately forecasted by manufacturer's guarantee, the cost of fuel to generate the additional steam required can be easily estimated. Then by plotting the temperature curve of the water supply and allowing for a fair differential temperature, the quantity of water required to condense the steam for full load of the unit can be figured for each season of the year. By comparing this with the fuel costs noted above, the final selection can be properly determined after securing estimates or proposals on various sizes of condensers and pumps.

Since the introduction of the steam turbine the condensing problem has become doubly important. With engines the gain in economy by the last one or two inches of vacuum is relatively very much smaller than with the turbine. Furthermore, the reduction in first cost, floor space, and the like, have demanded different types of condensers. The introduction of the low-pressure turbine also emphasizes the importance of high vacua essential to their successful operation.

The daily and annual load factor on the unit also have an important bearing on the condenser. Where the unit is to be operated continuously at or near full load the conditions noted above will apply, but where the load is fluctuating and averages considerably below the rated capacity, the effect on economy of the unit has important bearing only at hours of full or heavy load and should be considered only for those hours, because the water supply will be ample at other times.

The design of an air pump or dry-vacuum pump involves the general features of the air compressor. The variation in intake and discharge pressure is not great, but the volumes to be handled are enormous, owing to the low pressures. The important items outside the pump itself are, first, to keep the piping system from the point where the pressure goes below atmosphere to and including the condenser and its auxiliaries as nearly bottle tight as possible, and, second, to cool the air entering the pump and remove from it as much of the water vapor as possible. The first question is one of careful attention and inspection, and is often a very greatly neglected point in plant operation. If the engineer properly ininspects the system daily and watches the mercury column or gauge closely, he can very quickly detect any unusual amount of air leakage. Yet it is common to note the falling off of one to three inches in vacuum before any attention is paid to the matter, when a fraction of an inch should be an indication that something is wrong and requires immediate attention.

The second essential, namely, the cooling of the air and separation of the moisture, is a matter that must be considered in the design of the condenser itself.

In the jet condenser, particular attention should be given to the air offtake, which should be so designed that all the air must pass in intimate contact with the cold water entering the condenser chamber. In the surface condenser, attention should be paid to the proper distribution of baffle plates in order to accomplish this result as nearly as possible. The writer is of the opinion that in many cases the air should be drawn off through a separate chamber, in which it is cooled as nearly as possible to that of the entering water. This would reduce the volume of the air itself and would greatly reduce the volume of water vapor, and would enable a considerable reduction to be made both in the size of air pump and in the work the pump does.

The compression in the air pump should approach as nearly as possible a true isothermal, in order to reduce the power required for its operation to a minimum.

In operating air pumps many engineers start the pump, set it at its normal speed and let it run regardless of the load. The result is that the air pump does a great deal of unnecessary work, and at times it is pumping steam to a greater extent than air. This can often be quickly checked by slowing down the air pump materially without any effect upon the vacuum.

The surface condenser is used almost exclusively on all the large turbine installations, and has given better results than jet condensers ordinarily show. There seems to be no inherent advantage that would justify any appreciable difference between the two types of condensers. With the large turbine units the steam consumption per unit of output is as low as 14 lb. per kw-hr., and upon this basis the amount of surface per kilowatt of capacity required is very much less than in smaller units. With small units the ordinary installation requires four to five square feet of tube surface per kilowatt capacity, while on the large turbine the surface required varies from 1.75 to 2.5 sq. ft. The reduction in first cost per kilowatt of capacity in large-size units is therefore as great as 50 per cent. The surface condensing equipments installed in some of the larger stations produce continuously vacua in excess of 28 in. and have reached 29 in.

There seems to be no reason why a jet condenser should not produce equally good results if properly designed. It is true that the work required of the air pump on a jet condenser installation is in excess of that required on a surface condenser, but the decreased amount of cooling water necessary should more than offset the disadvantage of the extra quantity of air. The first cost of jet condensing equipment would not exceed 50 to 60 per cent. of the cost of sur-

face condensing equipment, and the repairs and maintenance should be much smaller. The surface condenser requires more attention, the surface must be kept clean and the tubes tight, and the best results can only be secured by constant attention.

A condenser of novel features has recently been introduced to this country from European practice. In this condenser the design of the chamber in a measure resembles the ordinary barometric condenser, the chief novelty being in the pump unit. The water pump and rotary air pump are both mounted on the same shaft and can be directly connected to engine, turbine or motor, as desired, making a very compact and simple unit. Tests on this condenser have shown frequently that the discharge temperature of the water can be maintained between one and three degrees of the temperature of steam. When the construction details of this condenser have been thoroughly worked out, the condenser should find a large field.

The selection of the pump-driving unit for any condensing installation must depend largely upon the other plant conditions. If the exhaust from these units can be advantageously used to heat the boiler feed water, the steam-driven pumps will invariably figure as the most desirable. Where the exhaust from other plant auxiliaries is sufficient for feed-water heating, or where economizers are used, the selection depends upon a comparison of cost of motor and steam-driven pumps and of the expenses for operating them. The general features of the much-discussed problem of motor *versus* steam-driven auxiliaries enters into the problem.

COOLING TOWERS.

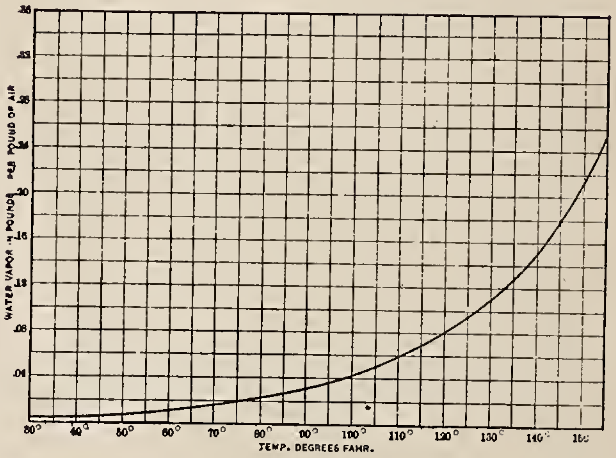
The design and operation of cooling towers is a matter so closely associated with the design and operation of condensers that the combination of condenser and tower must be considered as a single unit and the same general principles applied as noted above. In localities where a supply of condensing water is not obtainable, recourse must be had to the use of cooling towers. The general principles of the tower are in a measure a reverse proposition from those embodied in the condenser. The problem becomes one of dissipating to the atmosphere the greatest possible amount of heat from each pound of water with a minimum expense for fixed and operating charges.

Cooling towers are classified in two general classes, namely, forced-draft and natural-draft towers, the distinction being in the method of circulating the air in the towers. The comparison of the relative merits of the two types is one that involves the consideration of climatic conditions, of ground space, of the cost per unit of surface as compared with the cost of fans plus the operation of same and of the adaptability of towers of varying capacities to the condenser.

The climatic conditions, namely, temperature and humidity, are of greatest importance in cooling tower design, and on this account each installation must be treated as a separate problem, and there can be no standard sizes for towers of various caapcity that would be generally applicable to all locations. The greater portion of the heat extracted in a cooling tower goes to supply the latent heat of vaporization of enough water vapor to saturate the air leaving the tower. The balance goes directly to heat the air passing through the tower. During winter months the proportion of the heat that goes to heat the air is much greater than in the summer months and may exceed the amount of heat that is dissipated in supplying the latent heat of vaporization. Taking as an example an air temperature of 82° F. and supposing the air to be saturated (raining) at that temperature, and that the air is heated to 92° F. in the tower and leaves the tower saturated at that temperature, the heat extracted by each pound of air would be as follows:

To heat the air 10° F. would require 2.375 B.t.u. The saturated air at 92 degrees will contain 0.03289 lb. of water vapor and at 82 degrees it contained 0.02361, the balance of 0.00928 lb. having been accumulated in passing through the tower. The heat required to evaporate one pound of water from and at 90 degrees is 1051 B.t.u., and the heat extracted in evaporating 0.00928 lb. of water would be approximately 9.75 B.t.u. Therefore, each pound of water leaving the tower at 92 degrees would carry away 2.375+9.75, or 12.125 B.t.u., and the work done by the evaporation would represent about 80 per cent. of the total. If the air entering the cooling tower was not saturated it would be able to pick up a still greater quantity of water and the proportion of heat extraction evaporating would be still greater. In this connection it is interesting to note that where the air entering the tower is comparatively dry it is possible to cool the water below the temperature of the air, and this effect has been noted in several tests on a natural-draft tower in Denver. The effect is of course produced by the heat extracted from the water to supply water vapor partly or completely saturate the air, and this effect will continue even if the water is considerably colder than the air.

Attention is called to the accompanying saturation curve for air at 29.92 in. barometric pressure. The very rapid rise in the amount of water vapor required to saturate the air as the temperature increases indicates the greater opportunity for extraction of heat at the higher temperature and it becomes desirable to heat the air leaving the tower as high as possible. This in turn requires that the temperature of the water leaving the condenser and entering the tower be raised as nearly as possible to the temperature of the exhaust steam. For a given range in temperature in the tower it is readily seen that the warm air has a much greater effect, and the reduction of the temperature of the water to or below that of the entering air is more easily accomplished



than when it is cold. One pound of saturated air, heated from 90° F. and discharged as saturated air will extract approximately as much heat as one pound of air raised from 0 degree to 40° F. and saturated when leaving at that temperature.

Localities possessing dry climate are best suited for the use of cooling towers, and it is exceptional to find the temperature of the air very high before or during a rain-storm. On the other hand, moist climates do not as a rule have as high temperatures during the summer months. For average conditions a tower can usually be figured safely upon a basis of maximum temperature of 90° F. during a rain-storm when the air is saturated. On days when the temperature is in excess of 90° F. the humidity will be considerably below saturation, as a rule, and the capacity of the tower will equal that for the conditions named. Basing estimates upon the air supply as stated, the problem becomes one of determining the amount of surface required.

The amount of heat to be extracted from the water can be accurately estimated by the steam consumption of the unit and the quality of the steam entering the condenser. The temperature and humidity records should then be considered as outlined above and the steam economy of the unit at various vacua compared to note the

effects of periods of hot weather and the economical reduction of vacuum that can be allowed rather than to go to the increased expense for larger condenser and towers.

Allowing that the water leaves the condenser at a certain temperature and enters at a certain lower temperature, the quantity of water required is determined. In making these figures it will be seen that the widest possible range in temperature of the water should be secured. Then in cooling this amount of water in the cooling tower the amount of surface required must be calculated. This is is one of the most indefinite points in cooling tower design and is the most important one. The rate of transfer of heat from water to air, either direct or through a diaphragm, varies through rather wide limits. With increased circulation of the air the rate increases, but the exact ratio of increase is not definitely established. The effect upon the absorption of water to saturate the air is undoubtedly greatly increased by rapid circulation of the air. On the other hand, if the air is forced through the tower too rapidly it does not become fully saturated and therefore the quantity of air required is greatly increased. In the ordinary natural-draft tower the greatest care must be used to get full benefit of all the air passing through the tower, while in forced-draft towers there is always more or less water carried away mechanically and the water leaving the tower is seldom saturated, indicating that more air is being used than would be necessary in a properly designed tower.

The rate of transfer of heat from water to air through a metal diaphragm is about 2.5 B.t.u. per square foot per degree per hour. If the outer surface is kept wet the heat transfer is materially increased, and if, in addition, the air is circulated rapidly the rate of transfer can be increased to several times the figure named. In the cooling tower the heat is transferred directly from water to air and the amount of surface depends quite largely upon the rate of circulation of the air, and no definite figures were obtainable upon the transfer in forced-draft towers. By calculating this coefficient upon a natural-draft tower in Lincoln, Neb., a heat transfer of 6 to 8 B.t.u. per square foot per degree per hour was shown upon a series of tests. Using 7 B.t.u. as a basis it is seen that the surface required to produce very high vacua during hot weather would be enormous. Taking the temperature of steam at 28-in. vacuum at 102° F. and allowing five degrees differential between steam and discharge water, would make the temperature of the water entering the tower 97° F. If the air were up to 90° F. in temperature, this would allow a maximum working range of only seven degrees and the surface required would be 22 sq. ft. per pound of steam condensed per hour. For a differential of 10 degrees the surface required would be 15 sq. ft. for 20 degrees, 7.5 sq. ft., and for 30 degrees five square feet per pound of steam condensed per hour. In each of these cases the vacuum would be reduced and at the 30 degrees differential it would be 26 in.

In the case of the forced-draft tower the size of fan and power required for its operation would decrease in about the same ratio as the decrease in surface noted above by allowing larger differential temperatures and obtaining correspondingly smaller vacua. In either case the fixed and operating charges on condenser and cooling tower must be balanced against the cost of extra fuel, and the like, required when the vacuum is reduced in order to determine the most economical installation.

Various materials have been used for wetted surface in cooling towers. Rough boards have been successfully used, but they take up a great deal of room, and the cost per square foot of surface is high when compared with other materials. Wood blocks, tile, and the like, have been used largely in forced-draft towers, and the results are satisfactory except as to first cost. The use of curtains made of galvanized-wire screens has been tried, but the first cost is high and the screens are not entirely satisfactory in distributing the water. A number of tests have been made with burlap curtains, and the results thus far have been above expectations. The burlap is very cheap and is easily made into curtains. These curtains are comparatively light and easily suspended in the towers. The only difficulty has been to secure a long-thread burlap so that a portion of the threads will not wash out and enter the piping system. Some of these curtains are now four years old, and the expense for renewal will be nominal. Several suggestions have been made as to tarring or painting the curtains as a preservative, but the cost and value of these treatments are doubtful.

In the design of forced-draft towers the following conditions must be considered: (1) The tower should be laid out with great care to secure proper distribution of the air and water. (2) The fan capacity should be figured upon a basis of handling saturated air, and the path of the air should be such as to bring the water and air in intimate contact so that the air will leave the tower as nearly saturated as possible. (3) Care must be taken to prevent loss of water by being carried away mechanically with the air leaving the tower. (4) On account of the increased cost of pumping water to high heads, the tower should be as low as possible and the water pumped no higher than absolutely necessary. (5) In laying out the water distributing system care must be used to reduce the friction head to a minimum.

In combustion work it has been found that in forcing or pulling air through a fuel bed the induced draft which pulls the air through is much preferable to forced draft for securing proper distribution of the air. The distribution of the air in the fuel bed is much more uniform, and, especially in gas producers, a distinct advantage is gained in the suction-type producer. More fuel can be burned per square foot of grate surface and with less overventilation than with forced draft. The same general principles apply to air distribution in cooling towers, and it is the author's opinion that much more uniform and satisfactory results can be obtained by placing the fan at the top of the tower and drawing the air through the tower. On acount of the moisture present it would be necessary to protect the fan blades from rust by galvanizing or frequent painting. The results from combustion work would indicate at least 30 per cent. improvement and would reduce the amount of air required and the power consumed by the fans materially.

In the design of natural-draft towers the principles are very similar. These towers should be set in as open location as possible so that full advantage can be taken of winds to aid the draft created in the towers. Where set in open spaces it is advisable to have the sides, or at least a portion of each side, equipped with removable doors so that the air openings can be changed to suit the direction of the wind. In the tower the greatest freedom for air movement is necessary, and the design of the water distributing system must be made with a view of leaving as much free air space as possible. The passage of the air through the tower will create a certain amount of draft caused by heating of the air and the absorption of water vapor, which further reduces the density and increases the stack effect. The tower can be designed to create draft sufficient for all the air required, but it is usually desirable to use the added advantage of the winds wherever posible in assisting the air circulation. In spacing the curtains in the tower it is necessary to place them close enough together to get the full benefit of all the air passing; but, as pointed out, the distributing

troughs must be laid out to allow as free air travel as possible. If the amount of water flowing down the curtains is too great it will create a counter-effect to the draft and will retard circulation of air in the tower.

An important feature of the tower is to house the air openings properly, to prevent loss of water during high wind-storms. If no loss of water occurs, the amount of condensation, if the jet condenser is used, will be more than sufficient to supply the water evaporated in the tower. If a surface condenser is used, the make-up water required in the tower should not exceed and will ordinarily be somewhat less than the amount of water supplied to the boilers. Where a jet condenser is used, the cold-water supply to the boilers can be passed into the tower pit and condenser inlet and the water for boiler supply drawn from the hot water leaving the condenser.

In the design of the water distribution system, the friction head must be kept down as much as possible when proper distribution of the water is maintained. It is very essential that the water be distributed evenly over all of the curtains or wetted surface, and this as a rule necessitates some experimenting on the tower in order to reach all the curtain with an equal supply of water. An effective means of accomplishing the result is to distribute the water from two or more troughs. The water discharged from the pipe at two or more points in each trough will maintain practically uniform level in the troughs. The discharge from the main troughs should be through vertical slotted openings in the sides, so that the quantity discharged to each curtain will vary as the head of water in the troughs without creating any friction head. The individual troughs supplying each curtain should be made as narrow as possible in order to leave ample space between troughs for air openings. These troughs should discharge through slotted openings, similar to the main troughs, against a metal strip or vane which acts as the hanger for the curtains and on which the water is uniformly distributed across the full width of the curtain.

Cooling ponds with jets scattered through the pond and discharging into the air above the pond are used to some extent. The amount of power required for pumping the water is large, and the first cost, unless the pond is already in existence, is prohibitive. On very still days the capacity is limited, as wind is depended upon for air circulation. On days when the wind is brisk the loss of water carried off mechanically is excessive and the amount of make-up water is consequently increased.

Some very interesting experiments have been made on a combination of condenser and cooling tower in which the steam discharged from the unit enters coils of pipe or chambers over which water is sprayed and air rapidly circulated. This plan has shown some promising results. The amount of water required in the condenser is practically the same as the amount condensed. This plan could possibly be made feasible for small units, but for large units it could not be applied. Fair vacua were obtained on certain tests of this outfit at the Virginia Agricultural College.

The extension of this plan along the lines of the radiator of automobiles leads to an invaluable and very interesting problem, which merits some study for applications to small units.

The majority of the larger installations in this country are forced-draft towers, while Europeon practice seems to be toward using natural-draft towers wherever ground space permits. With plenty of ground space available the natural-draft tower should receive most careful consideration, and the application of a natural-draft tower to a condenser that will discharge the water practically at the temperature of the steam makes a very desirable combination for the average installation.

Distributing Transformers

E. G. REED

The purpose of this paper is to briefly trace the development of the distributing transformer; to show the essential requirements of transformers of this class; to discuss their electrical and mechanical characteristics, and to indicate their probable future development.

In the early days of the transformer it was used only for the distribution of electric current for lighting, directly to the consumer, but as the alternating-current system developed other transformers were required. The term "distibuting transformer," here used, is intended to apply to those units delivering energy directly to the user.*

HISTORICAL.

From the classical experiments of Joseph Henry, published in 1832, was developed the induction coil, which is the prototype of the modern transformer. The first practical transformer was patented in England in 1882 by Gaulard and Gibbs. The American patent rights were purchased in 1886 by the Westinghouse Company. The construction of the Gaulard and Gibbs transformer is shown in Fig. 1. From 1883 to 1885 William Stanley, Jr., while in the employ of George Westinghouse, experimented with the converter, the name by which the transformer was then commonly known. In 1885 Stanley built transformers of the type shown in Fig. 2, and this became the commercial form used by the Westinghouse Company for many years. During the year 1886 that company built transformers for commercial use, of the type shown in Fig. 3, the winding and magnetic circuit being substantially that shown in Fig. 2.

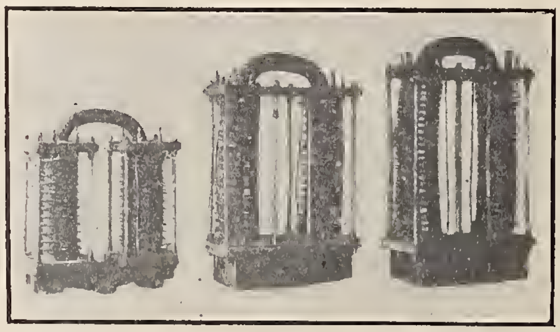


Fig. 1.—GAULARD AND GIBBS TRANSFORMER
Original British patents dated 1882

The terms "core" and "shell" type were introduced about this time to denote the difference between transformers like that of Gaulard and Gibbs, in which the iron forms a core or center portion on which the windings are placed, and those in which the iron encloses the coils like a shell, as in the Stanley form shown in Fig. 2.

In the years 1887 and 1888 an endeavor was made to secure legislation against the use of alternating current for the distribution of power, the experience of Mr. Westinghouse in the introduction of the alternating-current system of distribution, being, therefore, somewhat similar to his experience in introducing the air brake into general use. The Thomson-Houston Company brought out a shell-type transformer in the year 1888. This type of transformer,

*N. E. L. A., 1909.

shown in Fig. 4, continued to be used down to as late as 1895.

After the first commercial transformers were made, the immediate developments were improvements in detail on the shell type of construction. The use of oil as an insulating and cooling medium was generally adopted, and both the iron and copper losses

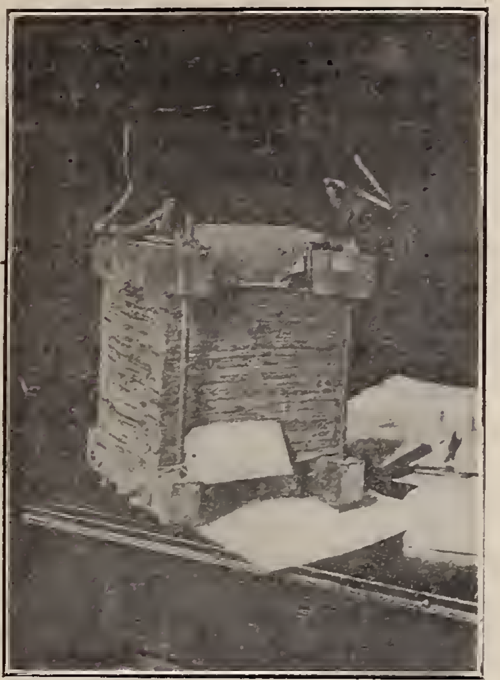


Fig. 2.—STANLEY TRANSFORMER AS BUILT IN 1885

were reduced and the regulation improved. The transformers were modified to meet the requirements of 60-cycle service, the first design being built for 133-cycle operation, this frequency being then in general use. About 1899 to 1901, designs were developed indicating a close approach to the ideal transformer, as in the Berry patents taken out in England about this time. (See Fig. 5.) The same ideas, however, were foreshadowed in the original patent (see Fig. 6) granted George Westinghouse, May 25, 1886.

Fig. 3.—EARLY WESTINGHOUSE TRANSFORMERS, MANUFACTURED IN 1886

The original conception has been developed toward the ideal construction, which, however, cannot be completely realized on account of limitations in the materials, iron and copper, of which actual transformers are constructed.

The ideal transformer may be described as the design in which the mean turn of both iron and copper will enclose a maximum area for a given amount of material. This will result in a design of the least amount of material and lowest cost to obtain a given performance. The ideal trans-

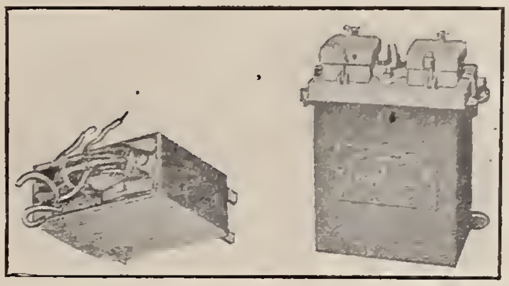


Fig. 4.—EARLY THOMSON-HOUSTON TRANSFORMER
Made in 1888

former, as shown in Fig. 7, is one in which either the iron or the winding is formed into an annular ring and the other elements into a circular form about this ring completely filling its opening. Further limitations beyond that of the materials used in building transformers, such as hand labor and the requirements of ventilation, space

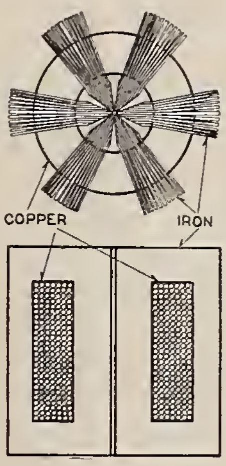


Fig. 5.—BERRY TRANSFORMER

for terminals, and other details of construction, prohibit the actual building of the ideal transformer.

Fig. 8 shows the construction of the latest form of the shell type for distributing transformers and is a practical construction approximating the ideal shape. The limitations im-

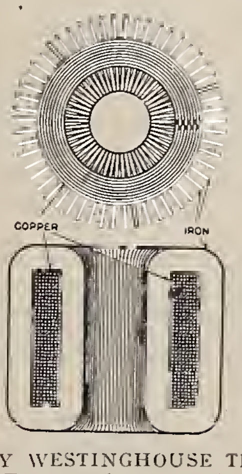


Fig. 6.—EARLY WESTINGHOUSE TRANSFORMER
Patent date, 1886

posed by the character of the magnetic materials used is aptly offset by increasing the section of the magnetic circuit outside of the winding. This permits an increase in the magnetic circuit without a corresponding change in the conductors which would have been necessary with the other

SHELL TYPE CORE TYPE
Fig. 7.—IDEAL TRANSFORMERS

forms of design. The core type of design, which is a counterpart of the shell form in Fig. 8, is shown in Fig. 9. The refinements found in the best modern designs of core and shell type reduce considerably the difference which formerly existed between them. In high-voltage work the core type of construction, depending on the size of the transformer, finds its best field, and hence both forms of construction are justified. The efficient disposition of the insulation possible with the core-type transformer in higher voltages is the reason for its use.

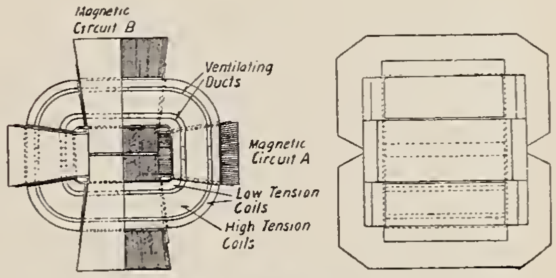


Fig. 8.—LATEST FORM OF THE SHELL-TYPE TRANSFORMER

The simplicity of the magnetic circuit in the best design of this improved form of the shell type is illustrated in Fig. 10 and its merits are shown by the test results given in Fig. 11. The shell type of transformer requires one group of coils, instead of two or four as in the core type. The addition of the two iron circuits to the former shell construction protects the remaining two sides of the coil and the winding is practically armored.

The comparatively recent advent of silicon or alloy steel has affected both the design and performance of distributing transformers. Its use does not change the relative economy of the different types of construction, but its increased cost does change the proportions of copper and iron in any particular design. The lower loss per unit of weight of the iron would naturally allow a saving of material for a given performance. This would result in an increase of the flux density in the iron, and of the current density in the copper, their upper limits being set by the magnetic saturation of

the iron and heating of the copper. The general effect of the better material on commercial transformers, however, has been to increase their efficiency, better their regulation and to reduce their size and weight without increased cost to the buyer.

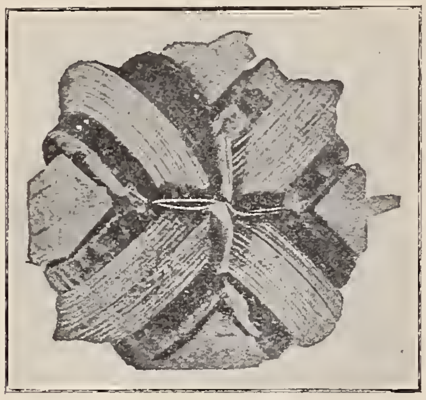


Fig. 9.—CORE-TYPE TRANSFORMER
Counterpart of latest shell-type

In the early days of transformer designing the proportions were worked out roughly by rule of thumb, the main requirement being to build transformers that would operate. For a considerable period it was thought that there were so many quantities involved in the design that it would not be practical to take them all into consideration and make a theoretical design. In the manufacture of modern transformers this method of treatment has been demonstrated to be the only successful one to use. The relative costs of iron and copper are taken into account, and the most efficient design is made for the existing market value of these materials. Mathematical methods of design produce

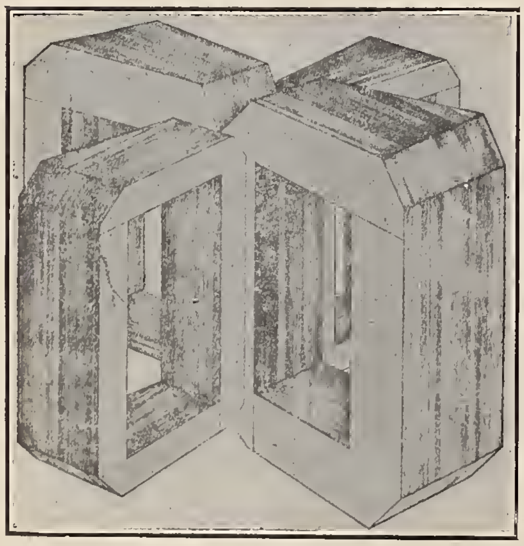


Fig. 10.—MAGNETIC CIRCUIT OF THE LATEST FORM OF THE SHELL-TYPE TRANSFORMER

transformers that are uniform in their characteristics, the sizes progressing in dimensions, weight and performance in a uniform manner. This is indicated in Fig. 11, showing the losses for a line of commercial transformers.

SERVICE REQUIREMENTS.

The service requirements of transformers mounted on poles or in manholes are identical as to performance, but differ in most other particulars. Regarding performance, it goes without saying that the iron and copper losses should be low; in fact, the development of distributing transformers during the past twenty years has been largely one of reducing these losses. Low iron loss is particularly important, since it is continuous and therefore should be smaller than the copper loss, which occurs only when the transformer is loaded. Since the regulation is practically proportional to the copper loss, the extent to which the iron loss of a transformer of given

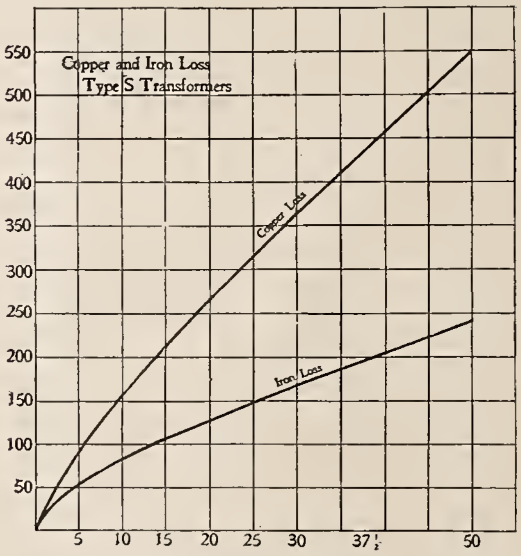


Fig. 11.—IRON AND COPPER LOSS CURVES
Transformer of recent design

cost may be reduced by increasing the copper loss is limited by the necessity of securing good regulation. For example, the regulation of a one k.v.a. transformer, as shown by the curves in Fig. 12, is 2.62 per cent., which value cannot be greatly increased without rendering the transformer unsuitable for ordinary service. On the other hand, the regulation of a 50 k.v.a. transformer is 1.15 per cent.,

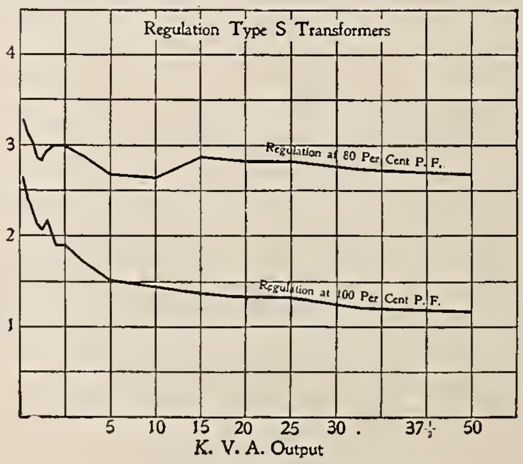


Fig. 12.—REGULATION CURVES
Transformer of recent design

and this value might be increased without jeopardizing satisfactory service. The iron loss might be reduced by increasing the copper loss if this change would result in a net saving. For a transformer of given cost, as the iron loss is reduced and the copper loss increased, a point is reached beyond which a further decrease in the iron loss can be made only by a very considerable increase in the copper loss. This is shown by the curve in Fig. 13, which represents the relation between the losses which can be obtained with various designs having the same cost. The curve shows that if the iron loss be decreased to 90 per cent. of its normal value, the copper loss increases to 113 per cent. of its original value. However, decreasing the iron loss to 60 per cent. of its normal value, would increase the copper loss to 183 per cent. of its original value. This should be taken into account in proportioning the losses, which for a given transformer should be so related that the cost of supplying them for a given period shall be a minimum.

It is usual to consider the total cost of supplying transformer losses to be made up of the actual cost of producing current, say one cent per kilowatt-hour, and a fixed charge for interest, depreciation, and the like, on the station equipment, of, say, \$20.00 per kilowatt-year. The total cost of supplying one kilowatt-year of iron loss at one cent per kilowatt-hour for 365 days of 24 hours, amounts to \$87.60 plus the fixed charge of \$20.00, or a total of \$107.60. Assuming the daily load on the transformer to be equal to four hours of full load, the actual cost of the power used per kilowatt of copper loss will be one-sixth of the cost of power used per kilowatt of iron loss, or one-sixth of \$87.60 equals \$14.60. Thus the total cost per kilowatt-year of rated transformer

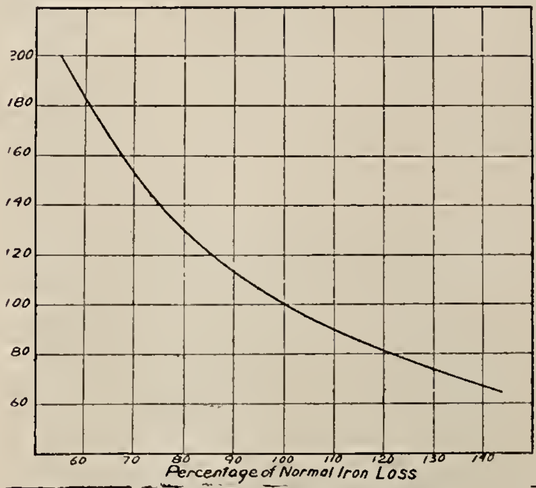


Fig. 13.—CURVE SHOWING RELATIVE VALUES OF IRON AND COPPER LOSSES

copper loss will be \$14.60 plus the fixed charge of \$20, or \$34.60. The cost of supplying the losses of a modern five k.v.a. transformer having an iron loss of 45 watts and a copper loss of 93 watts, will be:

Cost per year of iron loss equals
$0.045 \times \$107.60 = \$4.84$

Cost per year of copper loss equals
$0.093 \times \$34.60 = \$3.22$

Total cost \$8.06.

This transformer has a copper loss that is approximately 2.1 times its iron loss, and it can be shown theoretically that, for the cost of power as given above, the best results would be obtained if the copper loss were 2.4 times the iron loss. The losses of a line of commercial transformers are shown in Fig. 11, in which the average copper loss above the smaller sizes is 2.1 times the average iron loss.

The query next arises, why are transformers not made having lower losses than those just referred to? The answer to this is that improved apparatus is not readily saleable unless the saving resulting from its use is more than the cost of carrying the additional investment. If the five k.v.a. transformer before referred to costs $60 and the interest and depreciation on this investment is 15 per cent., the total annual cost of operating this unit is $9.00 plus $8.06 =$17.06. If it can be shown that the losses of this transformer can be reduced at a cost which will make the total cost of its operation less than $17.06 per year, a more economical transformer for these conditions could be designed. The performance of modern transformers is more the result of a growth and adjustment than of theoretical considerations. The factors entering into the cost of power are so variable, and the questions of transformer costs so intricate, that a general solution is hardly possible. It is usual for transformer manufacturers to carry two lines of transformers, one having relatively lower iron losses than the other, the difference in price being approximately 15 per cent. The curves in Fig. 14 show for what cost of power, fixed charges, and the like, it is equally economical to use either grade of transformer. For instance, if the anual cost of the equipment is $20.00 and interest and depreciation on the transformer investment is 15 per cent., and if power costs approximately 0.5 per cent. or more per hour, it is more economical to use the first-grade transformer. These curves are drawn for a particular size of transformer, taking into account its actual cost and losses and the difference in cost and performance between it and the corresponding size of the other line. The general results, however, will apply to a whole line of transformers, as they differ in all sizes by approximately the same amount in cost and performance.

The exciting current of a transformer may be defined as the current taken by the high-tension winding when the low-tension winding is not loaded. Heretofore the magnitude of the exciting current of distributing transformers has not been given much attention, due to the fact that with the older grades of iron a low exciting current naturally resulted from a normal design. The use of silicon steel has modified designs in such a way that without considerable care in design and manufacture high exciting current result. For this reason, today the question of exciting current must be considered when buying transformers. It is not generally appreciated that the exciting current of a transformer is the cause of a copper loss in the line and in the generator, which is continuous so long as the transformer is connected to the mains. This is a true energy loss and must be placed in the same class as the iron loss. With a load having 100 per cent. power-factor, the loss re-

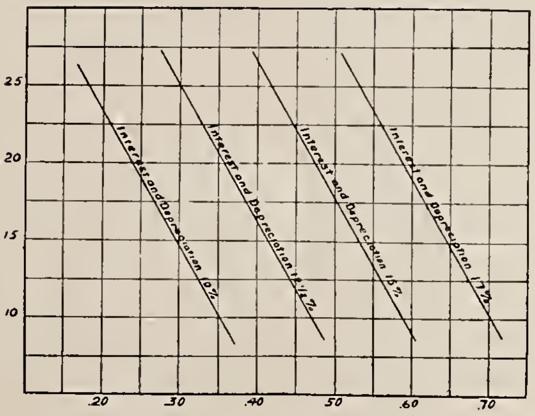


Fig. 14.—COST CURVES

Showing relative value to central station of transformers of different efficiencies for various values of power cost, interest and depreciation.

sulting from the exciting current is constant and independent of the value of the load. The lower the power-factor, the greater will be the copper loss due to the exciting current. For example, assume that a distributing line is loaded with transformers which take an exciting current such that the magnetizing component is five per cent. of the full-load current. How does the operating economy of this transformer compare with one having a magnetizing component of, say, 15 per cent., assuming that the power-factor of the load external to the transformer 100 per cent. and that the normal line loss is 15 per cent of the power delivered? Assuming further that the transformers have a normal iron loss of one per cent., the first case will result in a line copper loss which is equivalent to increasing the iron loss of the transformer by approximately four per cent. For the second case, a line copper loss results which is equivalent to increasing the iron loss of the transformers by approximately 34 per cent. In the case of a 60 per cent. power-factor, the first transformer produces line losses equal to increasing the iron loss approximately 125 per cent. and in the second case approximately 400 per cent. In the case of the transformer having 15 per cent magnetizing component, the increase in line loss will be equal to an increase in transformer iron loss from a minimum of 30 per cent. at 100 per cent. power-factor to a maximum of 400 per cent. at 60 per cent. power-factor, having intermediate values depending on the magnitude of the load and its power-factor. Hence the presence of large magnetizing current will, under certain conditions, produce much greater loss than the total iron loss of the transformer and on the score of efficiency it is important to consider magnetizing current as well as true iron loss. The exciting current of commercial transformers of various sizes is shown in Fig. 15.

Aside from this copper loss, a considerable portion of the generating equipment must be operated at periods of light load on the transformers merely to supply exciting current. The use of transformers having a high exciting current also causes a lower power-factor on the whole distributing system, thus affecting the regulation not only of the transmission line and the transformers, but the generating equipment as well. Thus,

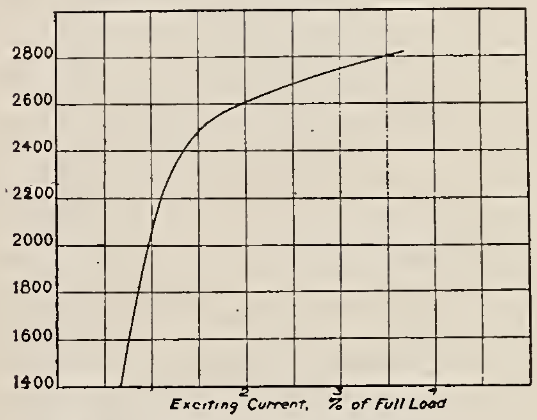


Fig. 15.—EXCITING CURRENT CURVE
Transformer of recent design

with a load that naturally has a good power-factor, the introduction of transformers with high exciting currents tends to materially reduce this power-factor. Again, with loads having low power-factors, the use of such transformers will still further reduce the power-factor. High exciting current indicates that the iron in the transformers is worked near the knee of the saturation curve, or a little past the knee. Thus an increase in the voltage of the system will run the saturation of the iron beyond the knee of the curve and produce an extremely high exciting current.

OPERATING CHARACTERISTICS.

The relative values of the iron and copper losses in a transformer may be varied by changing the voltage impressed on its primary winding, the load current also being changed so that its kilovolt-ampere output remains constant. The output of a transformer is regularly rated in kilovolt-amperes, or the products of the secondary voltage and the current de-

livered to the load. Thus if the voltage delivered by the transformer is decreased, the current must increase if its output is to remain constant. The induction in the magnetic circuit, varying with the impressed voltage, increases or decreases the iron loss. When the voltage is low the current in the winding is large, consequently the copper loss is increased, and when the voltage is high the current and the copper loss are low. The curves in Fig. 16 show in a graphical way the relation between the copper and iron losses and their sum as the impressed

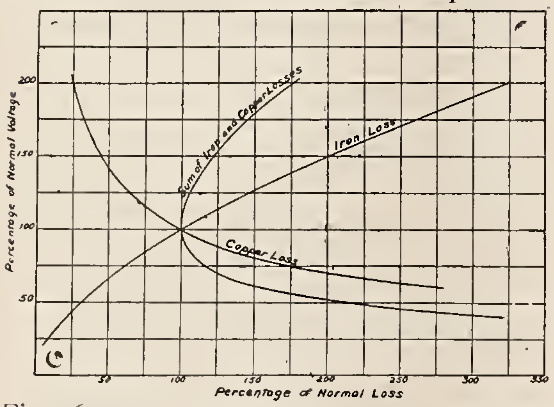


Fig. 16.—CURVES SHOWING CHANGE OF LOSSES WITH VARIATIONS IN IMPRESSED VOLTAGE WITH CONSTANT OUTPUT.

voltage varies; the kilovolt-ampere output remaining constant. It is apparent that when the iron loss reaches low values the copper loss increases very rapidly. On the other hand, when the copper loss in turn reaches its low values, the iron loss does not increase so rapidly as did the copper loss. It is interesting to note that as the iron loss increases and the copper loss decreases, the sum of the losses decreases until a minimum is reached, after which it again increases. It is apparent that the sum of the losses is a

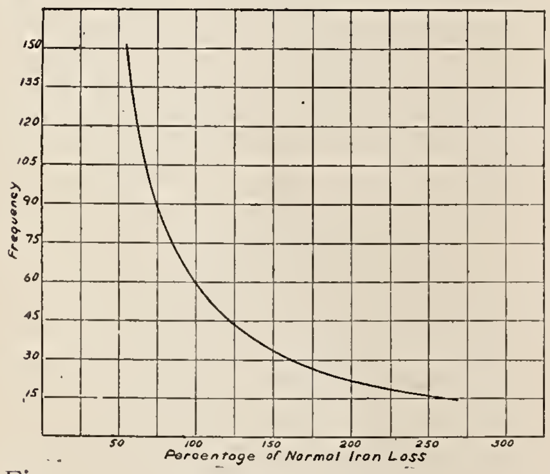


Fig. 17.—CURVE SHOWING CHANGE OF IRON LOSS WITH FREQUENCY

minimum somewhere in the region of equality of the iron and copper losses. In the variation of the losses by changing the impressed voltage, it has been assumed that the voltage change is not limited by the saturation of the iron. In a practical case, the saturation of the iron might prevent any considerable variation of the voltage above normal. The relation of the iron and copper losses in any transformer, if the sum of their losses is to be a minimum, is that the iron loss should be approximately 15 per cent. greater than the copper loss. This is a perfectly general relation, and for a transformer of any capacity, voltage or frequency and of any type of design, if the losses are in this relation their sum will be a minimum.

In the preceding case the losses were varied by changing the impressed voltage and keeping the output and frequency constant. Fig. 17 shows the variation of the iron loss for a given transformer with changing frequency at the supply circuit. The question is one of variable iron loss only, as evidently the copper loss is not affected by changing the frequency of the current. Assuming the iron loss and the copper loss to be constant, the output of a transformer is related to the frequency at which it is operated, as shown in Fig. 18. The output of a transformer, for example, at 25 cycles, is approximately 70 per cent. of its output at 60 cycles. Fig. 18 gives the output of a trans-

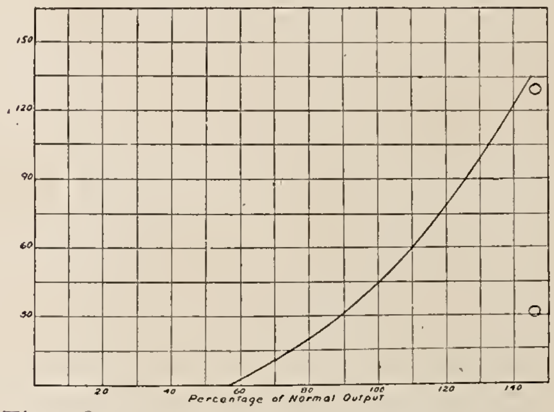


Fig. 18.—CURVE SHOWING CHANGE OF OUTPUT WITH FREQUENCY IN PER CENT. OF OUTPUT AT 60 CYCLES

former at various frequencies in terms of its output at 60 cycles.

It can also be shown that the output of a transformer is approximately proportional to the three-fourth power of its weight. This assumes that the loss densities in the materials, iron and copper, making up its structure are maintained constant.

Transformers operating at a temperature of 100° C. will probably soon fail, and assuming an average temperature of the air of 25° C., this limits the maximum permissible temperature rise of the transformer to less than 75° C. Allowing for a margin of, say 10 to 15° C., gives a safe operating temperature rise of from 60 to 65° C. This refers to the temperature rise of the windings and not that of the surrounding oil, which obviously must be cooler. In good commercial transformers, depending on the size and on the cooling efficiency of the oil ducts through the windings, the temperature of the windings is from 5 to 15 degrees above that of the hot oil in the upper part of the case. The temperature guarantee of standard distributing transformers is 50° C. rise of the windings after continuous operation at normal load. If this guarantee were based on oil temperatures, rather than that of the windings, a guarantee of approximately 40° C. could be made, instead of 50° C. In determining the permissible load at which commercial transformers can be operated for a given time, and the permissible time for a given load, this maximum operating temperature must not be exceeded. Having plotted from tests, the curves showing the increase of the temperature rise of the oil and windings with time, starting with 100 per cent. transformer load, it is possible to determine the corresponding curves for any other load.

The calculation of overload temperature curves is based on the fact that the temperature rise of the oil is proportional to the total loss in the transformer and the temperature rise of the windings above the oil is proportional to the copper loss. Suppose it is desired to draw the temperature rise curves for 125 per cent. load. Assume that after eight hours' operation at 100 per cent. load the oil rise is 34° C. and the rise of the windings is 45 degrees. If the normal iron loss of the transformer be 33 per cent. and the normal copper loss be 66 per cent. of the total loss, a load of 125 per cent. will produce a copper loss of 104 per cent., the copper loss increasing as the square of the load. The total loss for this load will then be 137 per cent., therefore the temperature rise of the oil will be $1.37 \times 34°$ C. $= 46°$ C. The rise of the copper above the oil will be $1.56 \times 11° = 17°$ C. The temperature rise of the copper will then be $46 + 17 = 63°$ C. This procedure can be repeated for a sufficient number of points to enable the construction of the complete temperature curve. The temperature rise curve of the wind-

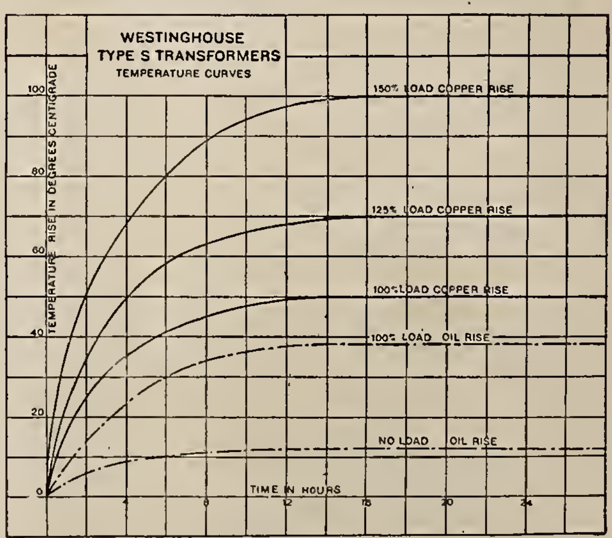


Fig. 19.—TEMPERATURE RISE CURVES

ings for no-load, that is, the temperature rise due to the core loss only, can be determined by the same method. If the normal core loss is 33 per cent. of the total loss, the temperature rise

of the oil and the winding also will, in this case, be $0.33 \times 34 = 11°$ C.

The curves given in Fig. 19, which show the rise of the oil at no-load and at 100 per cent. load and the copper at 100, 125 and 150 per cent. loads, have been determined by test, and they check up very closely with the theoretical curves as outlined above. The temperature rise of the oil is determined by a thermometer and of the windings by the increase of resistance method. These curves do not represent any particular size of transformer, but rather the characteristics of a modern line of distributing transformers of from 1 to 50 kilovolt-amperes.

From the temperature curves shown in Fig. 19, time over-load curves can be drawn, an example being shown in Fig. 20. These indicate the time required for any load to increase the temperature of the transformer to any specified temperature rise. If the transformer is cold when the load is applied, it will require a slightly longer time to reach the predetermined rise than if it has already attained the temperature due to the core loss. This difference is not considerable and for practical purposes may be ignored. From the curves given in Fig. 20, it is possible to determine the temperature rise of a transformer under almost any conditions that may arise in service. There are two kinds of problems:

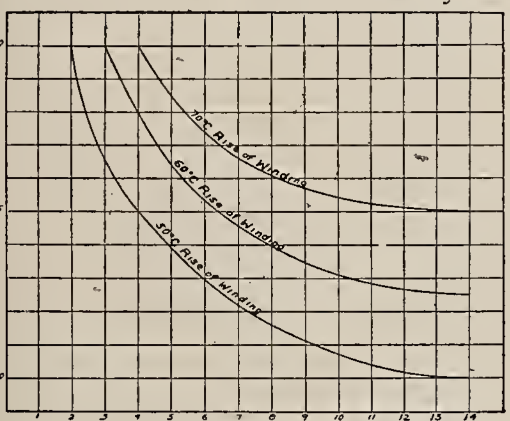


Fig. 20.—TIME OVERLOAD TEMPERATURE CURVES

First—What will be the temperature rise of a transformer under given conditions of load for a certain period of time?

Second—What period of time will a transformer carry a certain load without exceeding a limiting temperature rise?

As an example of the first case, suppose it is required to find the temperature rise of a transformer that is operating with no-load and then receives a 100 per cent. load for four hours, followed by a 150 per cent. load for two hours. From the temperature curves in Fig. 19, it is seen that the windings have approximately a 12-degree rise, due to the iron loss only. To obtain the temperature rise of the windings after four hours at 100 per cent. load, follow the 100 per cent. load temperature rise curve forward for a period of four hours from the point where it reached a temperatue rise of 12° C. This gives a temperature rise of approximately 38 degrees. When the 150 per cent. load is placed on the transformer it has a temperature rise of 38° C., and will then continue to rise in temperature as indicated by the 150 per cent. load curve. Starting from the 38° C. rise, on the 150 per cent. load temperature rise curve, a transformer at the end of a two-hour period will have reached an approximate temperature rise of 63°C. In this case its original temperature rise, due to its core loss, had little effect on its final temperature. Although it had a temperature rise of 12° C. when the 100 per cent. load was started, this increased its temperature rise only 2° C. at the end of the four-hour run at 100 per cent.

As an example of the second phase of the problem, suppose it is required to determine what load is required to produce a temperature rise of 70° C., after six hours' run. It is necessary in this case to refer to a 70-degree time overload curve. From the curve shown in Fig. 20, it is seen that a load of 137 per cent. is required to bring the transformer to the required rise.

FUTURE DEVELOPMENTS.

If the present iron is used at a higher induction it becomes oversaturated, giving high exciting currents. A betterment of the permeability would allow higher working densities, the design being modified so as to use less iron. In designing 25-cycle transformers it is necessary for magnetic purposes to use more iron than is desired, because of the low permeability of the silicon iron.

In general, a betterment of iron, without improving the permeability, can only result in lower losses and not a reduction of the cost of the transformers. In order to take full advantage of the reduced true loss, it would be necessary to increase the saturation beyond permissible values. Higher permeability and then lower losses will permit a distinct improvement in transformers.

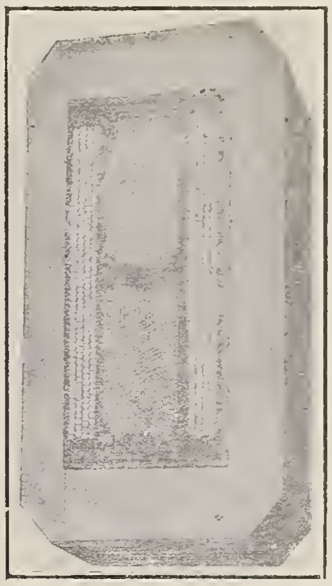


Fig. 21.—SECTION THROUGH TRANSFORMER MAGNETIC CIRCUIT AND WINDING

Another line of development is improvement of the insulation so as to require less space (see Fig. 21), permit increased temperatures and act as a heat conductor. This would allow higher copper density than is now permissible.

Residence Lighting in Detroit

By F. T. MATHER

The Edison Illuminating Company, Detroit, Mich.

Detroit with a population of about 360,000 has 13,000 homes lighted with electricity. We find no competition whatever in the high-class residences, comparatively little in the moderate-priced home and secure considerable business among owners of small cottages. The majority of homes of any pretensions whatever now being built are wired for our service and seldom piped for illuminating gas and the proportion of old homes being wired for electricity is increasing every year.*

These satisfactory conditions are due primarily to the rate which the Detroit company makes on residence lighting. The Detroit residence rate is differential and the rapid growth of this class of business dates from 1898 when this system of charge was adopted. Its peculiarity lies in the method used in determining the amount to be charged monthly to each customer at the primary rate, which is 14 cents per unit. This charge is reckoned on the number of rooms in each house. Unfinished attics, storerooms, laundries, closets and bath rooms are not counted in establishing the demand charge for any customer. Before adopting this method we ascertained by observation that the num-

*O. E. L. A., 1909.

ber of lights likely to be burned at the hour of the district maximum was actually very closely proportional to the number of these living rooms which we take as our basis of primary, or demand, charge. We have found the rule both practicable and satisfactory.

Current using devices such as fans, flat irons, disc, stoves, air heaters, cooking devices, etc., do not affect the demand charge, giving the customer the advantage of the secondary (4 cent) rate for the current used by electric utensils. This low price for current has done much to popularize the use of the electric appliances. We find that occupants of the modest home are desirous of electricity not for lighting only but also because of the labor-saving devices that may be operated with current. In such homes the woman of the house usually does her own laundry work and uses a washing machine and flat iron. One concern selling washing machines has placed four hundred and fifty of their machines on our circuits, mostly in houses where the laundry work is done by members of the family. We have between seven and eight thousand flat irons in use by our customers. We estimate the average monthly revenue from a flat iron to be about 50 cents. In the higher class of house the vacuum cleaner is coming into general use.

Such business as does not come easily on the basis of cost and convenience we procure by personal solicitation. The city is districted and a district man keeps in touch with the new buildings in his territory and also with removals and changes of occupants of houses along his route. We have listed all wired houses on our lines and if the occupant of a house is not using service our district man follows the matter up by periodical calls until the business is secured. This method rarely fails to finally secure a customer. When new houses are building the solicitor visits the builder and interests him in electric light, if he has not already decided to wire. The owner of the building is usually quick to appreciate the saving on decorations and furnishings when electric light is used; and that many landlords are now far sighted enough to profit by this point is shown by the fact that some of the Detroit real estate dealers with large rental lists are inserting a clause in their leases providing for the exclusive use of electric lighting in their rented residences. This action on the part of the landlords was not solicited by the Detroit lighting companies.

Electricity in the home is advertised in our daily papers from points of convenience, cleanliness, healthfulness, safety, etc. The heating, cooking and labor-saving devices have been exploited from time to time with pamphlets and booklets designed to attract the attention of the homemaker and housekeeper. A display room in connection with our main office is in charge of competent clerks who explain to visitors the uses of electrical appliances that may be used in the home. Our sales of this merchandise amount to about ten thousand dollars a year.

From a central station standpoint we consider residence business very desirable. It has been found by studying several groups of residences at different periods that the ratio of connected load to the district demand is more than four to one. We find this ratio increasing as the practice of adding lights for convenience in halls, basements, closets, etc., becomes more common. The daily maximum demand of this class of business is fairly constant from the middle of October until the end of June. The maximum does not change much throughout the year. Demand indicators installed in one hundred residences showed a reduction in the demand in June, July and August and the lowest reading is 75 per cent. of the winter maximum. The noticeable difference between the winter and summer bills for residence lighting is in the current consumption, which is considerably less during the summer months. The hour of the maximum demand of a residence district does not, according to our observation, vary. The maximum comes about fifteen minutes previous to the time of the evening meal and continues until about 8.00 P. M. and then falls slowly until 10.30 P. M. The residence district demand comes later than the business district demand and is falling at the time of the demand due to theatres and other places of entertainment is rising. The period of greatest sales to districts is in the winter months. The December sales in a middle-class district will be 13 or 14 per cent. of the annual sales for the year, while the monthly midsummer sales may be 4 or 5 per cent. of the annual sales. The accompanying table shows the distribution of sales to a group of one hundred residence customers that fairly represents our average residence business. This schedule shows that the monthly sales decrease from 10 per cent. in January to 4 per cent. in June, from which point they again increase to 13.2 in December. The total sales for six months from April to September inclusive amount to about 26 per cent. of annual sales, while the other 64 per cent. is sold during the winter months.

DATA ON 102 RESIDENCE CUSTOMERS FOR THE YEAR 1907.

Month	Units	Net Bills	Average Price Pr. Unit	Per Cent of Total Units
January	3874	$250.01	6.4	10.0
February	3222	220.60	6.8	8.4
March	3068	223.75	7.2	8.0
April	2438	197.87	7.5	6.9
May	2357	190.11	8.0	6.1
June	1625	156.71	9.0	4.2
July	1731	155.54	8.9	4.5
August	2097	167.11	7.9	5.5
September	3410	225.20	6.6	8.9
October	4846	291.10	6.0	12.6
November	4519	274.34	6.0	11.7
December	5079	293.25	5.7	13.2
12 months	38466	2,645.59	6.8	100.0

We find the annual load factor of residence lighting to be approximately one thousand hours use of the district demand. This figure was arrived at by analysis of the annual use of 905 residences in one group and is based strictly on the district demand, not the demand of the individual residence. The diversity factor connecting the demand of the residence district with the general demand is of considerable value.

The Supplying of Electric Current to Other Towns From a Centrally Located Station

By CLAUDE SMITH

Manager Bradford and Gettysburg Electric Light and Power Co., Bradford, Ohio

The problem of supplying current for lighting and small-power purposes in small towns that are unable to support a local generating station has proven to us to be only a financial problem and with the financial point as a beacon the mechanical and electrical ends were taken as of secondary importance in the construction of this plant. The Bradford and Gettysburg Light and Power Company was organized in the fall of 1908 for the purpose of building and operating a transmission line between the towns of Gettysburg and Bradford, Ohio. Ten-year street lighting contracts were obtained with both towns and a contract for current was entered into

with the Greenville Electric Light and Power Company, of Greenville, the county seat of Darke County.*

Gettysburg is a small farming settlement eight miles east of Greenville, while Bradford is strictly a railroad town twelve miles east of Greenville at the junction of the Indianapolis and Chicago divisions of the Pennsylvania Railroad. Gettysburg has a population of about 350, practically all of whom own their own homes. Bradford has a population of about 1600. The transmission line is built of No. 6 hard-drawn copper and designed for a maximum of 60 kw. Seven miles of the line is built on private right of way just outside the railroad property line. The remaining five miles is on a county road. The substation at Greenville is just outside of the city limits and contains the step-up transformers and the meter. At Gettysburg a 7.50 kw. transformer mounted on a pole feeds the three-wire secondary service of 110-220 volts. A small substation contains a 3-kw. selective tap transformer with 220 primary and a maximum secondary of 600 volts; the selective taps being for 12.50, 25, 37.50, 50 62.50, 75, 87.50 and 100 per cent. A small series regulator, ammeter wattmeter and an eight-day time switch completes the street lighting equipment. Eighteen 75-watt 60-cp. series tungsten lamps are operated on the streets, the service being all night every night from 30 min. after sundown to 30 min. before sunrise. The lamps are all permanently hung on 16.50-ft. rigid mast arms 16 ft. above the street.

The street lighting system of Bradford has a capacity of 150 lamps, 60 being in use at present, three 15-kw. step-down transformers are in use at the Bradford end and are connected in multiple feeding a main secondary system of two No. 0000 and one 00 line, the branches being of two No. 4 and one No. 6, the smallest feeders being two No. 6 and one No. 8, which makes the copper loss on the secondaries of such small value as to be imperceptible. The 15-kw. transformers are arranged for the two at the ends to be cut out of service during the day load, which greatly reduces the core losses and keeps the regulation. The maximum voltage during the day time being 118 to 120, the minimum at the peak load is 112 to 114. The series tungsten street lights have given excellent service and during the past four months only two lamps have been lost by burn-outs and 45 by defective joints between the filament and leading-in wires. Many of these lamps failed in the first 24 hours of burning. The lighting company does not handle any supplies or do any wiring but cooperate with the management in this matter. Tungsten lighting was pushed from the start. The commercial rates charged for current are first 30 kw. 12 cents; 30 to 60 kw. 9 cents; 60 to 90 kw. 6 cents, with a 1-cent per kw. discount for payment in 15 days. No meter rent is charged, the minimum charge being $1.00. The 60-watt lamp was adopted as the best for fighting gasoline as the operating cost is less and in small towns the financial end is the strongest argument that can be produced. In one instance a 15-light gasoline plant was displaced by 15 60-watt lamps, one 40-watt lamp and several 16 c-p. lamps for use in the basements and storage rooms. The gasoline had been costing $12.00 per month with $2.00 for the oil lamps in the basements and a night lamp. The first month's current (February) was $8.32 (March), $6.25 (April), $6.-00. In May this firm purchased a power coffee mill, the May bill being only $6.00. At the present time only three gasoline plants are left and they are less than a year old. The owners are willing to take on the electric at the first sign of trouble. The residence proposition has been very easy as the 24-hour service has been of such character as to commend itself to all. By pushing the 25 and 40-watt lamps a large number are coming in under the $1.00 minimum charge. This makes the introduction of flat irons and heating appliances very easy. The irons are put out on 30 days free trial. Nothing but high-grade irons are used and during the past month 20 irons have been sold. The first one to be returned is yet to arrive. Almost all the wiring has been installed by the management, who from experience has found that but a few people know what they want, and for this reason I have always offered my advice as to the proper equipment and in fact have refused to install work that was not standard. For tungsten lighting in many cases it was necessary to agree to make any desired change if the tungsten service was not satisfactory, hence all tungsten lamps have been installed well out of reach with suitable Holophane ware and independent switches, with the result that the breakage has been very small and service good. Where consumers are timid about trying irons, the outlet is installed free of charge and who would own a heating outlet and not have anything to put in it? It is a sure thing the neighbors would not forget that Mrs. Brown is using an electric iron. When once she has an outlet put in she is unable to find any good excuse to get rid of it. As by actual test the irons we put out are more economical than gasoline even at a 11-cent rate. On June the 1st, 105 meters were in service and 50 applications are on file. This service has been obtained without the least effort. Our aim is to install 300 meters in the two towns; when we get to the renters we expect to have house wiring to rent. The power question has as yet received but little attention. The gasoline power now in use does not total over 50 h-p. A small one-half horsepower motor is being used to demonstrate coffee mill service. This motor is belted to any old coffee mill that happens to be handy and after a few days use we go around and get an order for a direct connected outfit and every one is pleased. As to the efficiency of the plant, our loss for the month of March was less than 11 per cent., April 10 per cent., and May less than 10 per cent.

*O. E. L. A., 1909.

Factors that Should Be Considered in Making Street Lighting Contracts

By SAMUEL RUST

Greenville Electric Light & Power Company, Greenville, Ohio

There are 143 private corporations in Ohio engaged in the business of furnishing electricity to the public and of this number more than three-fourths are dependent upon street lighting of their respective municipalities for their financial success. In almost every other line of business when the success or failure of the entire concern depended upon the business of one customer the factors which enter into that business would be well known to both parties and a basis arrived at which would be satisfactory to all concerned in the contract. But in making street lighting contracts with municipalities the game so far has been a catch as you can affair with one side at least generally ignorant of what they were doing and suspicious of the other be-

cause they were ignorant and because they were of necessity compelled to deal with a monopoly.*

I think it will be agreed that if this part of the lighting business was understood by the municipalities as well as by the companies making the contracts, there would be better prices and more satisfactory contracts made.

It is not the intention of this paper to set out just what the prices for street lighting should be, as prices must vary with different localities and are dependent upon the amount of lighting, cost of fuel, cost of equipment and labor, kind of lights, lengths of contracts, etc., but there are some factors which enter into this branch of the lighting business which each party to the contract should know of and for which they should make due allowance in making such agreement. These factors I group into the following heads:

Length of contract, kind and number of lights, changes in position of lamps, outages, schedule burned, time of payment, costs of service and manner of contracting.

The length of time that a street lighting contract should run is a very essential factor to be considered by both parties to the bargain. The statutes of Ohio have fixed the maximum at ten years. The question is, should contracts be for any less period. If the company is a progressive one and keeps abreast of the times in adopting new improvements for their street lighting service, it should most assuredly not be less as every such company can count upon completely changing its street lighting equipment at least once in every ten years and this calls for an outlay that shorter time contracts will not justify. Every street lighting contract should provide that the company furnishing the lights should have the right to change their system to a newer or better system of equal or better intensity during the life of the contract, subject to the approval of the council or board making the contract. Instead of this provision injuring the municipality, it would benefit it by giving it the benefit of the improvements in electrical service which are appearing quite frequently and it would be an incentive to the company to furnish the city with the best and up-to-date service.

The proper method of dealing with outages is probably yet to be found. To compel the company to stand the exact price of the lamp when it is extinguished and should be burning is unfair to the company because of the equipment cost and fixed expenses which always exist, while to excuse the company for continued outage would likewise be unfair to the municipality. A good plan is to agree in the contract just what the outage should be per hour per lamp and it is suggested that the amount be two-thirds of the price received for the lighting of the lamp.

The kind of lamps to be used in lighting a town or city must depend somewhat upon the size of the municipality. Companies should be careful not to overlight a city in the beginning, as all municipalities grow rapidly and there is a constant increase in the number of lights wanted, the lighting bill may become too great in comparison to other city expenditures and produce dissatisfaction. While most municipalities do not make any mistake in this regard and are generally underlighted, there are some that have more lights than the city can well afford to pay for. This is like overselling a man in goods. He may pay for the goods but always results in a dissatisfied customer. So far there has been nothing invented for street lighting superior to the arc lamp. Its reliability, invention of its rays and ease of arranging its circuits had made it a favorite in any contract for street lights. In view of the recent inventions of the series tungstens, a price should always be agreed to for the installation of smaller units in out-of-the-way places in order that the city may light dark spots at a less cost than the arc lamp, which is too large for the purpose. Series tungsten are now made to fit the amperage of almost every size arc lamp and can be installed on the same circuit and operated simultaneously with the arc lamps. Reports from this class of lighting are all favorable as to its satisfactory operation and length of life. In the smaller municipalities it is a question whether the series tungsten will not in time supplant arc lighting entirely. Its economy of consumption and consequently lower price will enable the introduction of a largely increased number and avoid the shadows of foliage which is always dense in the smaller towns.

The number of lights that a municipality can use will determine in some measure the price that should be paid. At the end of this paper will be found an estimate of the cost of operating a 100-lamp street lighting outfit and it may be safely said that if the number is decreased the cost is increased and further that the price for a street lamp should not be fixed without taking into consideration the fact that the fixed expenses of the plant, sometimes called overhead expenses, will be the same whether 50 or 100 are contracted for.

The schedule that lamps are to be burned must also depend upon the size of the municipality. The writer is inclined to think that it is a mistake to furnish all night and every night service in towns of less than 5000 inhabitants, for such towns a moonlight schedule is preferable, but every contract should provide that in case the nights are cloudy or stormy, the lights should be burned during such conditions. Where the town is above 5000 and under 10,000 inhabitants, it is a very good plan to have the contract provide for four nights off in each month, unless they are stormy or cloudy. By doing this the plant is enabled to make repairs to its arc lighting equipment, without sustaining outages, and plants in cities of this size cannot afford to have so large an equipment as will guarantee continuous service. Cities that are above 10,000 will usually require all night and every night service, and cities of this class will usually justify a sufficiently extensive electrical equipment, that will enable the company to give everyday service on its street lighting service without inconvenience.

The costs which enter into street lighting should receive very careful consideration from the company. The writer is of the opinion that many street lighting contracts are made below actual cost. The following figures are based upon the average cost of a small plant of 100 arc-light capacity, taking into consideration cost of construction, maintenance and operation and using the standard enclosed arc system:

I estimate that each lamp will consume 600 watts per hour, and the time of burning 4000 hours per year, this will make a total consumption of 2400 kilowatt hours, or 3.217 horse-power hours per lamp per year. Estimating that the average small plant will require six pounds of coal per horse-power, the coal consumption for each lamp would be 9.65 tons, which figured at $2.50 per ton in front of the boilers, would be $24.12. The lamp will have to be trimmed about 50 times, and I estimate the cost of trimming at $1.00. It will consume 50 pairs of carbons, which I figure at $2.30. The repairing, time and material would amount to $5.00, cost of installing about $120.00 per lamp and figuring 10 per cent. depreciation, would amount to $12.00 per year. Cost of labor and salaries would aggregate $12.00 additional and the interest upon the investment $7.20, or a total cost of $63.62 per year. That these figures are certainly low, I would refer to the report of the commission appointed for St. Louis, to investigate the advisability of that city providing its own street lighting system, in which they found that the cost of operating an arc lamp for a city the size of St. Louis, would be approximately near $70.00 per annum.

*O. E. L. A., 1909.

Lifting Magnets

Although the first commercial lifting magnet was made more than a dozen years ago it is only within the past two or three years that lifting magnets have come to be regarded as indispensable adjuncts to plans handling large quantities of pig iron, scrap or heavy castings.

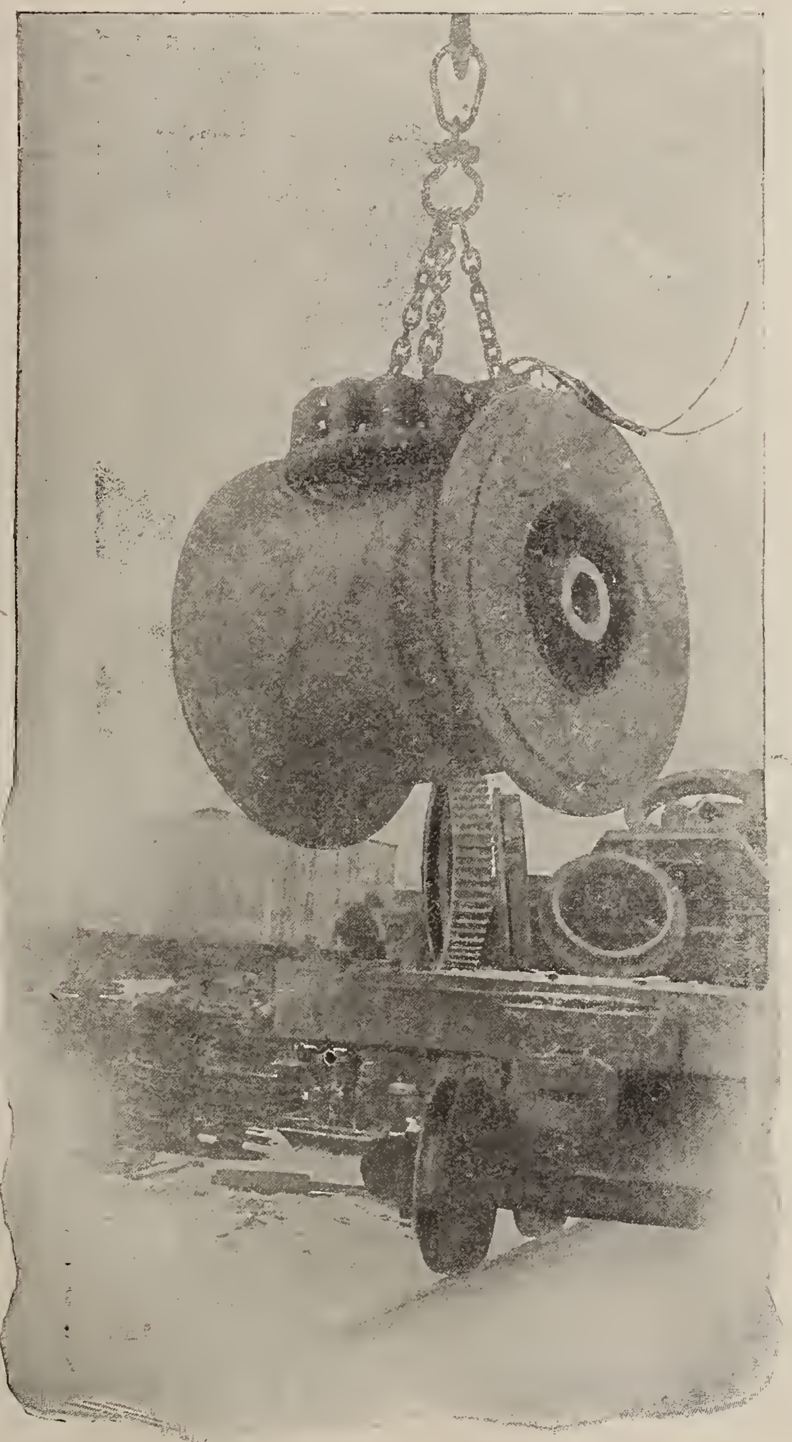
This tardy recognition of what has proven to be a great labor-saving device cannot be justly attributed to lack of appreciation of the advantages of lifting magnets on the part of those engaged in the iron and steel industries, but has been due, rather, to a well-founded belief that the earlier types of lifting magnets were more or less experimental.

Up to within a comparatively recent period lifting magnets for handling pig iron, scrap, etc., were unduly heavy and wofully inefficient, and even when improved to a point that permitted of their successful employment their cost was prohibitive to any but the largest industrial plants. Today it is possible to purchase for less than one-half the former price a magnet weighing only 2750 lb. which will lift as much, or more, than the old-style 5500-lb. magnet.

In January, 1907, there was placed on the market a lifting magnet designed by engineers who for years have devoted themselves to problems involving electric and magnetic control. This magnet was lighter than any existing magnet of equal size, and developed under repeated tests a lifting capacity from 25 to 40 per cent. greater than magnets then in use. It possessed several distinctive features which were at once recognized as essential to good lifting magnet design.

Instead of constructing the coil of cotton-covered wire, as was the general practice at the time, the coil of the magnet was built up of alternate layers of strap copper and asbestos ribbon. This form of construction (giving a rectangular instead of a circular cross section) made it possible to crowd more copper into a given space (increasing the lifting capacity of the magnet coil), while the substitution of asbestos for the cotton insulation used in other magnets rendered the magnet absolutely fire-proof, permitting it to be worked at a higher temperature without detrimental effects.

Furthermore, instead of permitting the magnet body itself to be subjected to the continued hammering of the metal handled, the designers protected the under face of the body casting

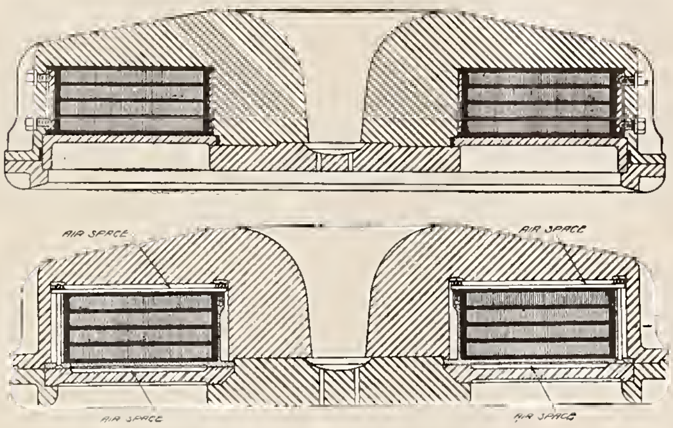


36-INCH MAGNET, PICKING UP 3500-LB. WINDING DRUM AT WORKS OF BUCYRUS SHOVEL CO., MILWAUKEE

36-INCH MAGNET, HANDLING HEAVY CASTINGS. THE CRANE OPERATOR CAN PERFORM WORK OF THIS SORT WITHOUT THE ASSISTANCE OF GROUND MEN. THERE IS NO HOISTING TACKLE TO BE ADJUSTED

with removable pole shoes, on which the brunt of the wear and tear falls, and which can be renewed at slight expense when worn out.

Still another improvement was the substitution of a manganese steel coil-shield for the brass shield formerly used. Most important of all was the recognition of the fact that the problem of heat radiation presented by a



CROSS SECTION OF MAGNETS

lifting magnet is similar to that of an enclosed rheostat.

THE PROBLEM OF THE MAGNET DESIGNER.

A lifting magnet may be considered as a bundle of ampere turns enclosed in a casing of magnetic material—cast iron, or steel. Assuming proper design, the greater the product of turns multiplied by current the greater will be the lifting capacity; and the greater the actual current taken by the magnet the higher will be its efficiency, since the proportion of live load to dead weight will be increased. The problem of the magnet designer, then, becomes that of locating the greatest number of ampere turns in the least space and of carrying the greatest amount of current in the conductor.

Copper, the metal always used for magnet coils, possesses a positive temperature co-efficient, its ohmic resistance increasing with increase in temperature. A lifting magnet will easily dissipate from its outside surface double the wattage that can be used in the coil, even assuming absolutely perfect conditions for heat radiation to be present. The limiting feature in magnet design, therefore, is the temperature rise of the coil. If too great (aside from the heat effects on the insulation) the result will be a reduction in efficiency due to the increase in coil resistance and consequent reduction of current and ampere turns. Hence it follows that to secure maximum efficiency throughout the working day the best possible conditions for conducting heat from the coil to the outside surface of the magnet must be present.

The cross sections shown illustrate the difference between a magnet constructed along lines tending to promote rapid conduction of heat from the coil to the radiating surfaces of the magnet, and one in which no such careful provision for heat conduction is apparent. In the latter case it will be noted that air spaces are introduced between the coil and the magnet frame, a form of construction which instead of aiding in the dissipation of heat generated in the

43-INCH MAGNET, PICKING UP AXLE BUTTS FROM SCRAP PILE

magnet coil actually tends to conserve it.

In the upper magnet note that the coil is clamped tightly between the body of the magnet and the coil-shield, whereas in the magnet illustrated below air chambers are introduced above and below the coil.

Compare the cross sections of the two magnets bearing in mind the following facts:

1. That heat does not travel well across joints between opposed surfaces. These must be reduced to a minimum.

2. That dead air spaces are the best heat insulators known. These must be eliminated as utterly opposed to good performance.

3. That heat generated in the winding is conducted to the casing, not from ribbon to ribbon and thence to the outside periphery, but from one section, or layer, of the coil to another, across the insulating barriers to the top and bottom surfaces of the magnet.

Magnets that possess dead air spaces, and a multiplicity of joints in the path of heat conduction are totally at variance with any accepted standard of electrical design, and this defiance of natural law can have only detrimental effects. If such magnets contain as many ampere turns and use as much current as a magnet properly constructed the interference with heat conduction *must* result in higher coil temperature and reduced lifting capacity after comparatively short pe-

riods of service. If, initially, such magnets use less current, thereby reducing coil temperature, the lifting capacity is reduced from the beginning, since the number of turns which can be gotten into a given space is fixed within narrow limits and decreases as the decreasing section of the conductor increases the relative space occupied by the insulation.

In order to secure maximum operating efficiency a lifting magnet must possess:

1. *Maximum Number of Turns*—Obtained by employing thin copper strap for the winding and asbestos ribbon for insulating between turns, thus securing maximum space efficiency.

2. *Maximum Current Flow*—The result of the rectangular winding section, high space efficiency and consequent reduction of mean length of turn.

3. *Maximum Heat Dissipating Capacity*—Due to the elimination of dead air spaces and joints in the path of heat conduction, and to the clamping of the winding positively between the upper and lower portions of the casing.

LIFTING CAPACITY OF MAGNETS.

The efficiency of lifting magnets depends on so many contingencies that no manufacturer can guarantee that his magnet will handle a given number of pounds unless he is informed as to the nature of the material to be handled, the manner of its piling, etc. The magnetic permeability of the metal constituting the load, inequalities of surface, nature of piling—these, and many other considerations, tend to influence the lifting capacity of magnets.

While it is not possible to furnish an accurate estimate of the work which a lifting magnet will accomplish without knowing in advance the conditions under which it will be operated the following information furnished by the Cutler-Hammer Co. will enable one to calculate the approximate probable saving that would be effected by installing a magnet.

36-*in. Magnet*—Weighs approximately 1850 lb. and requires about 17.50 amperes at 220 volts for its proper excitation. Its lifting capacity, based on averaging a number of tests on various classes of material, has been found to range from 800 to 1000 lb.

43-*in. Magnet*—Weighs approximately 2800 lb. and requires for its excitation 30 amperes at 220 volts. Its lifting capacity will average from 1300 to 1500 lb. per lift.

50-*in. Magnet*—Weighs approximately 5000 lb. and requires 40 amperes at 220 volts for its proper excitation. Its lifting capacity will average from 1800 to 2000 lb. per lift.

These figures are based on handling pig iron, bloom and axle butts, crop ends of rails and billets, miscellaneous scrap and similar material. Where large single objects, such as skull-cracker balls, steel beams, castings, etc., are handled the weight of the average lift will greatly exceed the figures given.

CURRENT CONSUMPTION

The coil of a lifting magnet is a device for transforming electrical energy into magnetic energy. The greater the number of amperes passing through a given coil the stronger will be the attractive force of the magnet. Hence, assuming proper design in other particulars, the greatest lifting power will be found in magnets which consume the greatest amount of current.

Strangely enough there has been put forward the undoubted and fallacious statement that some magnets do an amazing amount of lifting on a phenomenally small amount of current. With as much truth might it be urged that the law of gravitation could be cheated as to state that the law of magnetic forces could be defrauded in the design of large and massive magnets. Let us assume two magnets, one taking 40 amperes and one 30 amperes.

Taking the maximum current consumption in each case and assuming both magnets to remain in circuit for one hour and the cost of current to be 3 cents per kilowatt-hour (which is much in excess of actual cost of current in large industrial plants) it is evident that the current consumption of the magnet taking only 30 amperes will be 6.6 kw-hr., costing 19.8 cents, while that of the magnet taking 40 amperes will be 8.8 kw-hr., costing 26.4 cents—a difference of 6.6 cents in favor of the magnet taking least current.

On this showing alone the magnet taking the greater amount of current would seem to be the more expensive of the two, but assuming that a difference of 25 per cent. in current consumption will result in a difference of *only 5 per cent.* in lifting capacity it can be shown that in unloading a single car of pig iron the 40-ampere magnet will perform the work not only in a shorter time but at less expense than the 30-ampere magnet.

It must be remembered that cost of current for energizing the magnet is not the only item of expense to be considered. Loads handled by lifting magnets must be hoisted by the electric crane to which the magnet is attached and in most cases must not only be hoisted but must be conveyed as well. This means power consumption on the part of the hoist and travel motors of the crane.

Assume that two competitive magnets—A and B—are tried out under similar conditions, namely, each to unload a car containing 200,000 lb. of pig iron, the same crane to be used in each test.

Time required for crane to lift magnet clear of the car, transport it with its load to the stock pile, drop load and return to car is assumed to be one minute. Magnets are assumed to be in circuit one-half of the time required for each cycle of the unloading operation and out of circuit during the return trip to the car.

Current consumption of crane motors is assumed to be 20,000 watts per hour at a cost of 3 cents per kw-hr., and cost of labor (crane operator) is figured at 20 cents per hour, making the total cost of operating crane 80 cents per hour.

Magnet A requires 40 amperes at 220 volts for its proper excitation and lifts an average load of 1500 lb., while magnet B takes 25 per cent. less current and lifts 5 per cent. less material.

The above figures are based on an actual test furnished by the Cutler-Hammer Co., except the cost of current which has been increased from 1 cent per kw-hr. to 3 cents, which is believed to be the maximum cost of current in small industrial plants.

Computation shows the following:

Magnet A will unload the 200,000 lb. of pig iron in 134 trips, while magnet B will be obliged to make 141 trips.

Time consumed by magnet A will be 2 hr. and 14 min., while magnet B will require 7 min. more.

Cost of current required for energizing magnet A during the 67 min. it is in circuit will be 30 cents, while cost of current for magnet B will be only 23 cents.

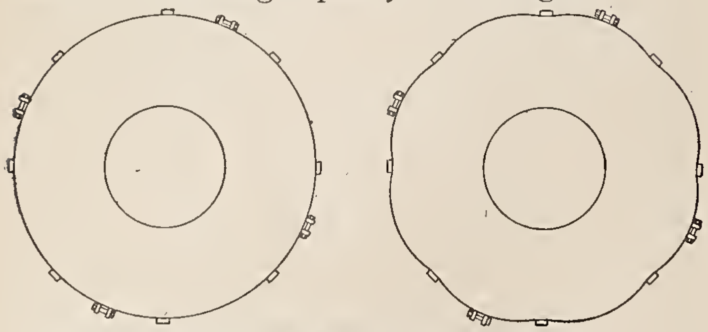
But—cost of operating crane will be only $1.79 in the case of magnet A as against $1.88 for magnet B.

While the figures given above show only a slight difference in the cost of unloading a single car it will be noted that the difference *is in favor* of the magnet consuming the most current, and that there is also a saving in time amounting to about 35 minutes in the working day. Moreover, the figures given assume a difference of only 5 per cent. in the lifting capacity of the two magnets. Assuming 25 per cent. greater efficiency for magnet A, instead of 5 per cent., the saving in time would amount to 35 min. *on each car,* or more than 2 hours per day. In cases where the pig iron or scrap can be dropped as soon as the magnet is clear of the car the time consumed in unloading can be greatly reduced. Fig-

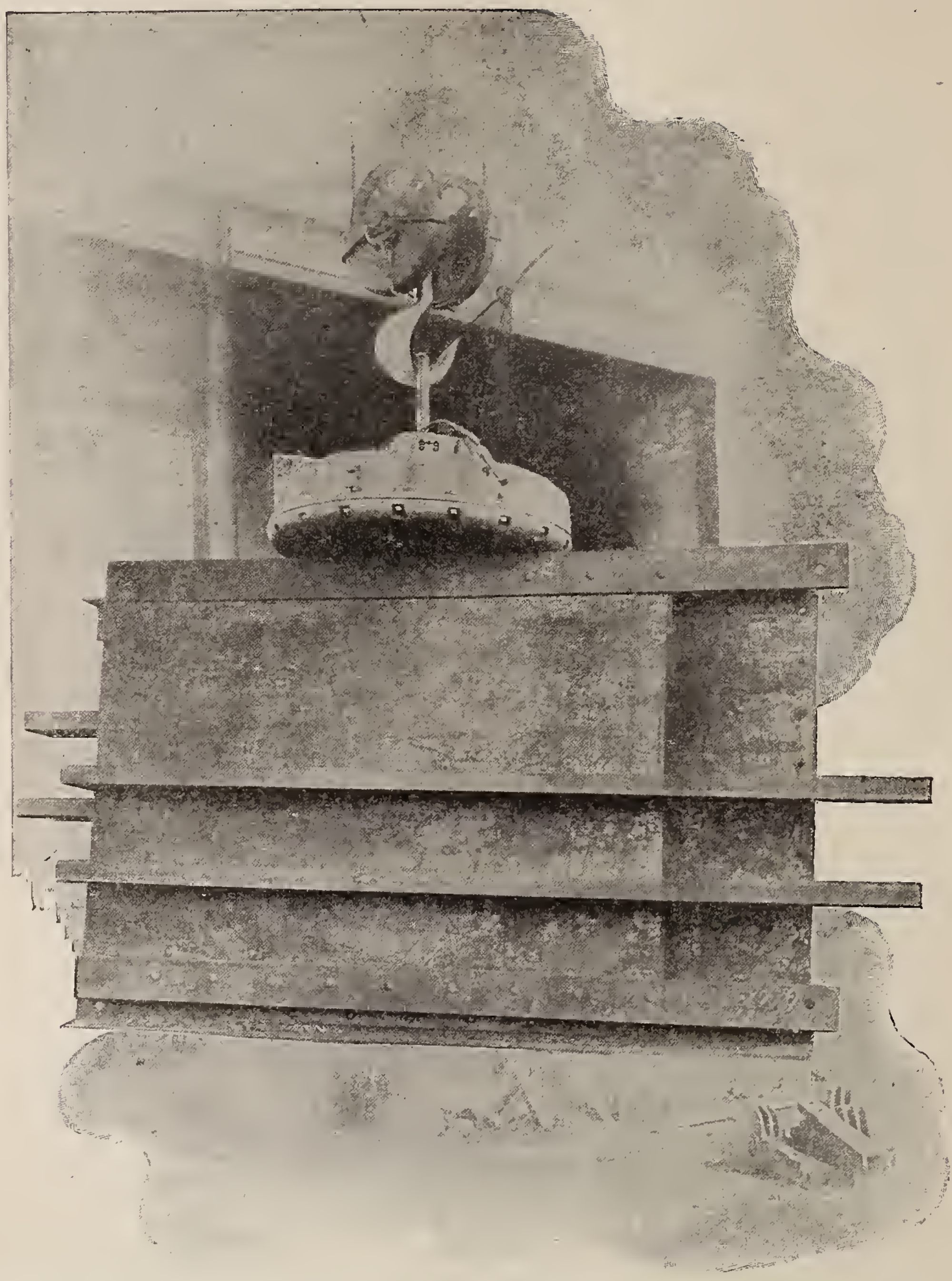
ures furnished by a large Pittsburg steel mill show that 196,300 lb. of pig iron have been unloaded with a Cutler-Hammer magnet in 1 hr. and 6 min., at a total cost of *less than half a cent per ton.*

THE MAGNET COIL.

No single feature of a lifting magnet is so important as the coil, on the design and construction of which the lifting capacity of the magnet largely depends. In very small lifting magnets wire coils may be used to advantage but in large magnets designed for handling pig iron and scrap it is necessary to secure the highest space efficiency in order to obtain maximum lifting capacity. The highest space efficiency is obtained by constructing the coil of thin copper strap and using asbestos ribbon for insulating between the successive turns of the winding. This method of constructing the coil was first used in Cutler-Hammer magnets and proved to be so great an improvement over the old wire coil that the latter have been practically driven out of the market.



THE DIAGRAM ON THE LEFT ILLUSTRATES THE CUTLER-HAMMER METHOD OF CLAMPING THE COIL—A METHOD THAT ANCHORS THE WINDING FIRMLY IN ITS PLACE WHILE PROVIDING FOR THE INEVITABLE EXPANSION DUE TO INCREASE IN COIL TEMPERATURE, AS ILLUSTRATED IN DIAGRAM ON THE RIGHT



43-INCH MAGNET, USED IN CONSTRUCTION WORK. MAGNET IS SHOWN HANDLING SECTION OF AN OPEN HEARTH FURNACE. NO SLINGERS ARE NEEDED WHERE LIFTING MAGNETS ARE EMPLOYED

The coil and casing of a lifting magnet must be so assembled as to form a compact unit structure, the winding being securely anchored to the frame in every direction—top, bottom and radially. This is accomplished in Cutler-Hammer magnets by so proportioning the coil, coil-shield and magnet frame that when assembled the coil is gripped firmly between the upper and lower surfaces of the magnet body, this intimate contact again aiding in heat radiation.

Lateral movement of the coil is prevented, first by the inner pole of the magnet, which extends through the center of the coil, and second by heavy bolts which extend through the body of the magnet and bear on the periphery of the coil. These bolts are provided with lock washers and are sealed with a water-proof compound.

To prevent "creeping" of the coil the winding is securely clamped with metal bands before being inserted in the magnet frame.

The construction described positively prevents any slipping of the coil, no matter how violent may be the shocks to which the magnet is subjected, while at the same time it provides for the inevitable expansion and contraction of the winding due to variations in the working temperature of the magnet.

This point has been overlooked by manufacturers who wind their coils upon a metal spool, or bobbin. No method of anchoring the coil will serve to prevent the winding from "creeping" unless in addition to guarding against the effects of external shock careful provision is also made against the powerful internal force at work when the coil expands under the influence of heat. The use of a metal bobbin adds, of course, to the dead weight of the magnet and possesses the further disadvantage of introducing additional joints and air spaces in the path of heat conduction.

THE COIL SHIELD

Brass was formerly used for the coil-shield of lifting magnets. It possessed the property of being non-magnetic (which all coil-shields must be), but the disadvantage of being too soft to stand the continued hammering of countless tons of pig iron, scrap and similar material. The manufacturers of the Cutler-Hammer magnet were the first to construct coil-shields of manganese steel. This metal is an ideal one for the purpose. It is non-magnetic, like brass, and so hard that no amount of hammering can dent it. It is, in fact, too hard to be machined, but is susceptible to grinding.

The manganese coil shields used in Cutler-Hammer magnets are first cast as accurately as possible and are then ground until they exactly fit into the magnet frame. When inserted in the frame and sealed with a water-proof compound, the joint is absolutely impervious to moisture. The water-tightness of these magnets is guaranteed and they can be used out of doors in all weathers without fear that the coil will become grounded through moisture finding its way into the interior of the frame.

When in place the coil-shield is securely clamped between the solid body

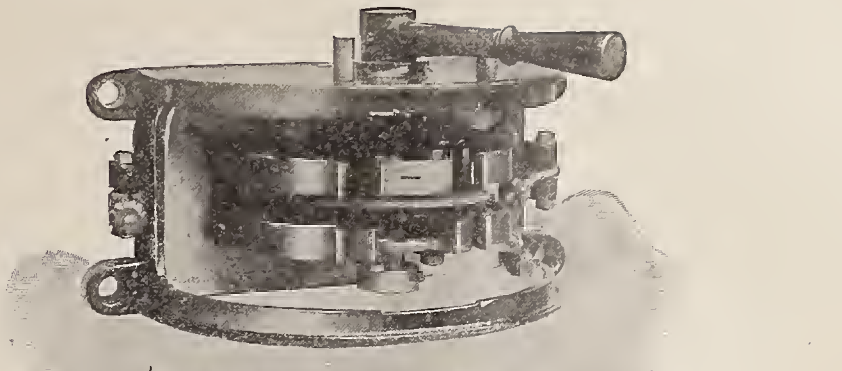
of the magnet and the removable pole shoes. It is made sufficiently heavy to withstand all shocks and transmit them to the casing without affecting the winding. This renders unnecessary resort to such objectionable expedients as cushion spaces and shock absorbers which mean more joints and more dead air spaces in the path of heat conduction.

THE TERMINAL BOX.

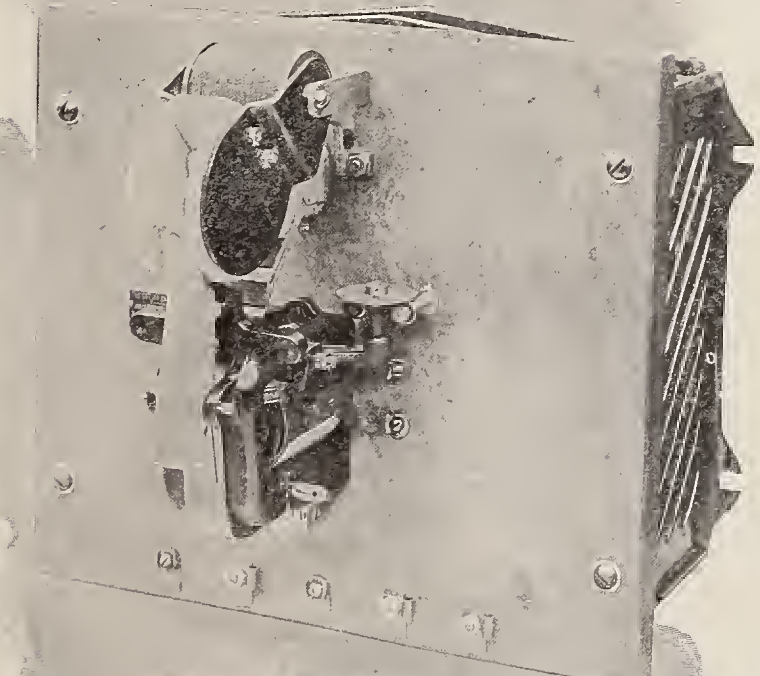
Simple as the terminal box of a magnet may appear to the casual observer, the development of the proper form of box has been one of the most troublesome details that the magnet manufacturer has been called upon to work out.

It is essential that this box (through which issues the cable connected to the coil) should be able to withstand the hard knocks which it may accidentally receive in service, and it is no less essential that it shall be absolutely water-tight, since water in the interior of a lifting magnet will ground the coil and render the magnet useless for the time being.

The first requisite is attained by providing a terminal box whose sides are integral with the body of the magnet. Such a box can easily be made water-tight by means of a close fitting cover provided with a heavy gasket, but experience has shown that if it becomes necessary to open up a terminal box while the magnet is in service there is a fair chance that it will not be properly closed again. The only safe rule to follow is to make the necessity for removing the cover of the box as remote a contingency as possible.



MASTER CONTROLLER
(COVER REMOVED FROM FRONT OF CASE)



DISCHARGE RESISTANCE
AND CLAPPER TYPE CONTACTOR.

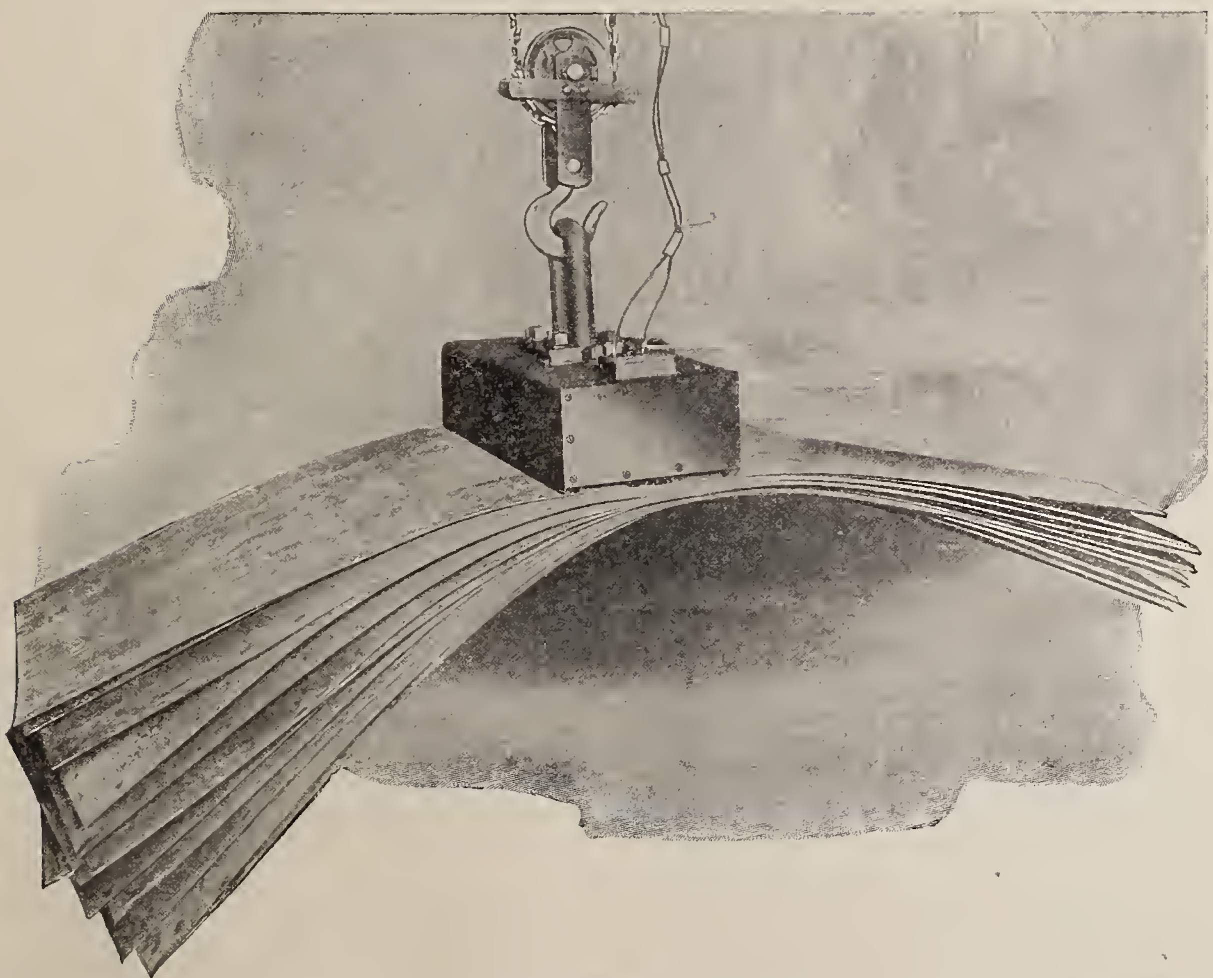


PLATE MAGNET LIFTING 910 LB. OF SHEET STEEL. THE FLEXIBLE NATURE OF THIS MATERIAL MAKES IT DIFFICULT TO HANDLE OWING TO ITS TENDENCY TO TEAR AWAY FROM THE MAGNET POLES. MUCH LARGER LIFTS CAN BE SECURED WHEN HANDLING HEAVY PLATE, RAILS, ETC.

With this end in view the leads from the magnet coil are brought up into the terminal box by means of heavy terminal studs, the upper ends of which are located in a counter-sink within the box. From these studs flexible leads emerge from the box through marine stuffing boxes and are secured to an auxiliary block mounted on top of the magnet adjacent to the box and protected on either side by heavy cast steel ribs. After all internal connections have been made the terminal box is filled with a pitch-like compound and the cover is firmly bolted down. Binding posts for the magnet leads are attached to the auxiliary block, enabling connections to be made or damaged leads to be replaced without disturbing the hood of the terminal box.

RENEWABLE POLE SHOES.

The pole shoe of a lifting magnet may be likened to the sole of a shoe—it is the part subjected to the greatest wear and tear. The advantage of casting the pole shoes of a magnet separate from the magnet frame, and hence readily renewable at slight expense, is obvious.

It should be noted in this connection that *through bolts* (not cap screws or studs) are used for securing the pole shoes to the magnet frame. Those who have ever endeavored to remove a cap screw or stud that has rusted in will appreciate the reason for using through bolts. With both ends of a refractory bolt accessible it is an easy matter to chisel off the nut, knock out the shank of the old bolt and insert a new one. This is a small matter in itself, but it is significant as indicating how carefully minor details have been considered in the design of Cutler-Hammer magnets.

METHOD OF CONTROL

With every Cutler-Hammer magnet of large size (36 in. and upwards) a drum type master controller and discharge resistance are furnished.

The control switch consists of two parts, the master controller and a solenoid operated, clapper type, contactor. These and the resistance forming part of the controlling system are illustrated herewith, the contactor being mounted on the face of the box containing the resistance. The master controller should be installed in the crane cab within convenient reach of the operator, while the contactor and resistance may be secured to any portion of the cab, either inside or out.

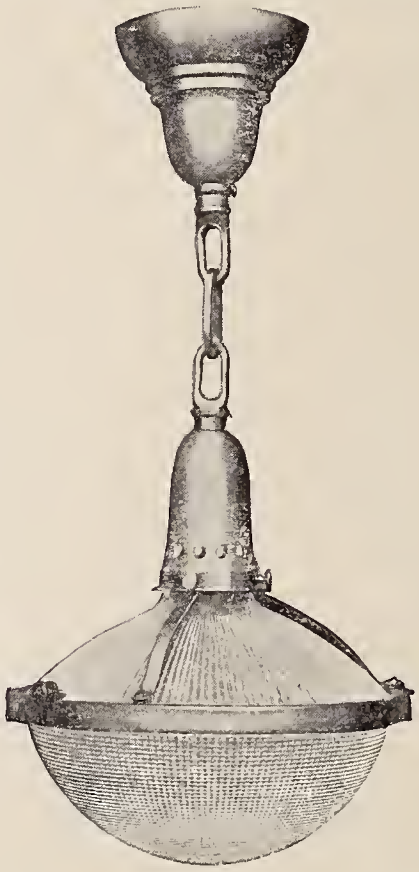
When the circuit is suddenly opened on a magnet coil there is a strong inductive reaction, or kick, the effect of which is to induce a high voltage at the terminals of the coil. Constant repetitions of this kick will sooner or later break down the strongest insulation unless provision is made for guarding against this induced voltage and dissipating its energy outside of the coil. In the Cutler-Hammer system of control the force of this inductive reaction is rendered harmless by automatically shunting the discharge resistance across the magnet terminals just prior to the opening of the magnet circuit and automatically disconnecting it just prior to the re-establishment of the circuit.

For ordinary service the master controller illustrated will prove entirely satisfactory. When, however, conditions are such that it is desirable to release the load instantly a reversing controller can be furnished. This not only opens the circuit but reverses the current in the coil, overcoming the residual magnetism that causes the load to cling to the magnet for a second or two after the circuit is opened.

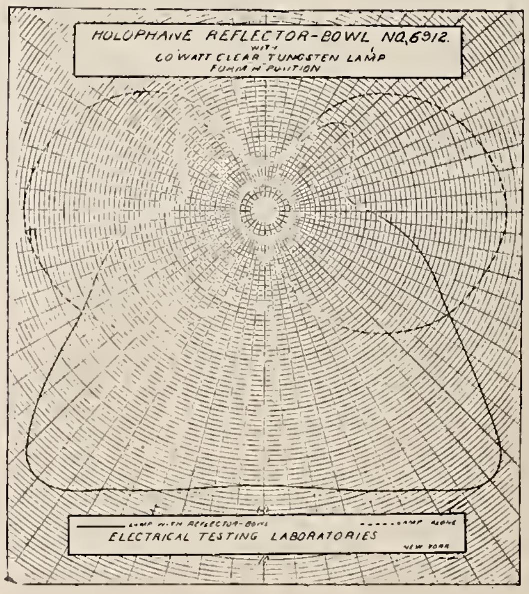
Homer Niesz has resigned his position with the Commonwealth Edison Co. to become manager of the Cosmopolitan Electric Co., Chicago. His position as assistant to Second Vice-President Ferguson will be filled by Mr. Peter Junkersfeld, who has been electrical engineer of the company for some years. His position has been filled by promoting R. F. Schuchardt, who has heretofore been engineer of electrical construction.

New Holophane Clusters

The Holophane Company, Newark, Ohio, has introduced improvements in the glass equipment of the Holophane "arcs" or clusters whereby a much better distribution of light is secured. The comparative curve here published indicates the improvement in this regard of the new units over the old.



A separable cluster body also is now supplied so that the new arrangement can be taken apart and the glassware cleaned without breaking the electrical connection. The standard finish of the clusters in future will be brush brass. Square-linked chain is used for the suspension, and a separable canopy is supplied, which does away with the necessity of a long nipple at the ceiling.



Cleaning the Water Leg

According to W. H. Wakeman, who writes in *Graphite*, "It is difficult to keep the water leg of a vertical boiler clean and in good order, because it is comparatively cool, and as there is no circulation of water at this point, sediment settles here, and unless it is removed at frequent intervals it becomes baked on the iron and thus forms into scale. In a certain plant where there are several of these boilers in use, the engineer keeps a chain in the water leg of each, and every time that a boiler is cleaned this chain is drawn back and forth, thus stirring up the mud and making it an easy matter to wash it out without further trouble. Hand holes are provided for washing mud off from the crown sheet.

"The lower part of this boiler is larger in diameter than the upper shell, and the two parts are connected by a peculiar shaped plate, as shown, for the following reason: The tubes and the outer shell do not expand and contract alike, hence this form of a connection is provided, as it springs enough to compensate for this difference.

"The water legs of all such boilers are liable to become corroded and thus rendered unsafe for high pressures."

W. A. Reichert, for the past three years advertisting manager for the Fort Wayne Electric Works, Fort Wayne, Ind., has resigned to accept a similar position with The Power and Illuminating Engineering Company of Alliance, Ohio. This company is a commercial organization co-operating with central stations to increase the day load on their plants.

Catalogue Notes

"How to Save Coal" is discussed from the point of view of recovering waste heat in the chimney flue gases in a neat little booklet, which is being distributed by the Green Fuel Economizer Co., of Matteawan, N. Y. The booklet further describes the construction of the Green Economizer, illustrating the new extended top header, the new bottom header, especially designed to avoid choking from soot, the new sectional covering and other improved features. There are several illustrations of large plants, such as the D. L. & W. terminal power plant, which have recently been equipped with Green economizers and Green mechanical draft fans.

A New Tungsten Wrinkle

Oxnard, Cal., May 12, 1909.

Gentlemen:

We are pleased to offer an "idea" which may be of value to other companies in our line.

Before the commercially approved advent of the tungsten lamp, the streets of two of our towns were being lighted by ordinary 16 and 32-c.p. carbon filament incandescent lamps of 250 volts connected in multiple and current furnished on meter measurement. The streets in both of these towns were from 60 to 80 ft. wide, and lamps were suspended to hang in street centers by wires leading from poles on each side of streets. The weight of the Cutter street hoods, with which each lamp was equipped, maintained a comparatively steady position of each. Wishing to benefit by the efficiency of the tungstens and at the same time to furnish a much-increased street illumination, escaping at the same time large additional investment which accompanied a proposed change to series tungstens, we contracted (after tests of two 110-volt tungstens in series across the 250-volt service) with both city governments to furnish double candle-power upon a flat-rate basis at an increased cost to them of but approximately 55 per cent. Thus we find that the regular 110-volt multiple tungsten lamp stands punishment very nicely in a swinging position in a section which is often subjected to high winds, and our installation is, we believe, the first of its kind in the country.

Very truly yours,
Ventura County Power Co.
By H. R. Staples,
Ass't to the President.

The Compensarc

The need of some kind of a device for controlling arc lamps on moving-picture machines is obvious when it is known that moving-picture machine arc lamps operate at approximately 35 volts at the arc, while the voltage obtainable from practically all commercial lighting circuits is either 110 volts or 220 volts. Some electrical device must of necessity, therefore, be used between the line and the lamp to take care of the difference in voltage. Formerly iron wire or grid resistance rheostats were used. Their use, however, resulted in a waste of all that energy supplied from the line over and above that actually required by the lamp. Progressive managers are now using compensarcs instead of rheostats and thus save all that amount originally wasted.

The compensarc therefore must of necessity be invaluable to all moving-picture theaters operating their arc lamps from alternating-current circuits. The Compensarc cannot be used on direct-current circuits. It is in reality a special type of adjustable auto-transformer.

The great saving in power resulting from the use of the compensarc, with the superior quality of light in color, intensity and stability, make it a prime favorite with all moving-picture men who have tried it.

This compensarc is known as Type A, Form 4, and is rated at two kilowatts for 110 volts or 2.5 k.w. for 220 volts, and wound for either 60 cycles or 133 cycles, as may be desired.

The core of the compensarc is made of the highest grade sheet steel laminations, similar to standard transformer construction. The outer surface of the core is fully exposed to the air. The coils are mounted within the core and are completely protected and thoroughly insulated. Core and coils are given vacuum treatment, making them moisture and waterproof.

The assembled core and coils are supported by a cast-iron base having four legs, which hold the compensarc at a convenient height from the floor. The case is also of cast-iron and rests on the top of the core. It is liberally ventilated and encloses the ends of the coils and protects the connections on the inside. A slate top supports the switch blade and clips. The slate top, case and base are securely held together by four long, heavy bolts, one passing through each corner of the slate top, case and base outside the core.

A horizontal, three-step, continuous circuit switch is mounted on the slate top, providing three adjustments for intensity of light. Each adjustment is so designed that it maintains approximately the same voltage at the arc while passing from one step to the next without at any time opening the circuit, which would consequently break the arc and produce flickering.

There is no waiting for the arc to settle and become steady before the intensity of the light can be determined. The compensarc increases or decreases the intensity of light without a flicker.

A cast-iron cover over the slate top completely encloses the switch blade and contacts, making it impossible for accidental short circuits to occur, and also removes all danger to the operator. The terminals to the line and lamp are brought out through porcelain insulators in the cover. The lamp terminals are plainly designated by the word "lamp" cast on the cover where the terminals come through. With a little care the compensarc can be installed by any operator.

As to appearance it is decidedly neat and symmetrical, plain, but not homely, a desirable addition to any operating room. It is extremely simple to operate—one hand on the switch handle controls everything.

The compensarc is approved by the National Board of Fire Underwriters. There is positively no fire risk, as there is no noticeable rise in temperature even after several pictures have been run through the machine.

Quality of light is so important in moving-picture shows that it really makes or mars their success. The compensarc provides a clear, white, steady light.

The compensarc is very substantially made and maintains its usefulness indefinitely. It cannot be short-circuited. Even though the switch blade is at an intermediate point and thus bridging two adjacent contacts, it will not burn out. The adjustments possible with the compensarc are very essential to successful moving-picture work, and the fact that the compensarc provides these adjustments without breaking the circuit and putting out the light makes it all the more desirable.

The compensarc saves 66 2-3 per cent. on light bills for moving-picture arc lamps.

Important Development in Bituminous Gas Producers

For a number of years The Westinghouse Machine Company has been engaged in the development of a satisfactory form of producer suitable for gasifying the usual grades of bituminous fuels. The unusual difficulties encountered in the utilization of this kind of fuel have resulted in the trying out of many different types, both of the producer itself and of the necessary auxiliaries for producing clean gas. For the past year and a half, however, the company has been engaged in carrying out upon a commercial scale a producer plant which is now upon the market. These tests have not been conducted with a toy apparatus, but with a full-sized equipment of 175 h.p., including a standard gas-engine of about the same power, by means of which the actual power value of the gas produced and the over-all efficiency obtainable were determined without possibility of error.

The above-mentioned tests were brought to a conclusion on April 3d by drawing the fire in the producer after it had been in continuous operation on various loads and on various fuels for a year past, these twelve months having been devoted to tests of one to four weeks' duration, both ten and twenty-four hours per day on standard fuels available for power purposes. These fuels included Pittsburg slack and run-of-mine, lignites

from Northern Colorado, Texas and South America, also peat and other fuels from various parts of the country. Most of the tests the load on the equipment was maintained at full rating, although one special test of one month and a half duration was made to determine accurately the standby loss of the producer standing idle.

The drawing of this fire after one year's operation was made the occasion of a demonstration of the producer plant before government officials and engineers from various parts of the country especially interested in bituminous gas practice.

The fire was drawn without trouble or interruption, as large clinker formations were entirely absent, although the producer had, just previous to this occasion, been running on a full-load test for one month, using Pittsburg coal. The lining of the producer was found to be practically intact and in quite good enough condition for continued operation for an unlimited period.

A detailed examination of the piping leading from the producer house to the engine on test, showed that during this long period of operation there had been no deposits of tar or lampblack. As a matter of fact, this piping had not been examined for about two years and a half of producer experimentation.

The most important feature of the demonstration was the entire absence of tar formed in the producer gas. A similar examination of the mixing and inlet valves of the engine which has been used for the past year on this test showed practically no deposits of tar or lampblack, such as would interfere with the operation of the engine. The Westinghouse plant uses no tar extractors, as no tar is made, simply a static washer of small size in the place of the usual bulky coke scrubber. A rotary exhauster draws the gas from the fuel bed and delivers it to the engine at a definite pressure.

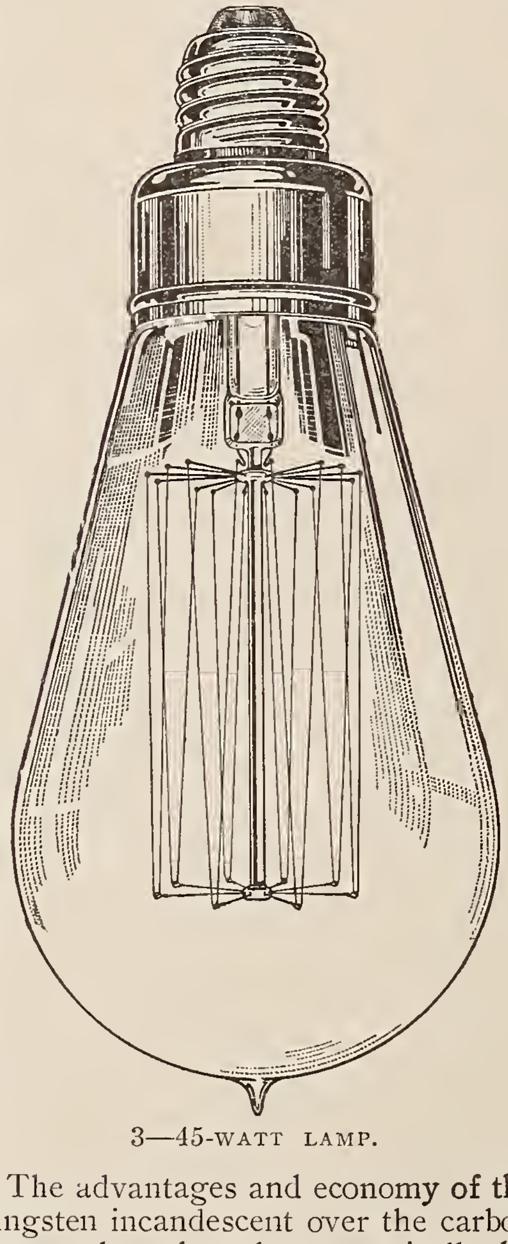
No gas holder is used in this process, as the producer regulation is entirely automatic. The gas produced has a moderate heat value suitable for high compressions in the gas-engine and is uniform and clean, average samples showing not more than 0.02 to 0.03 grains per cubit foot impurities.

The ash is fairly clean, and analysis of samples from time to time shows that not more than 1 per cent. to 3 per cent. of the combustible in the coal escapes in the ash.

The various fuels which have been used in this producer on test have been gasified successfully and have run as high as 34 per cent. moisture, 35 per cent. volatile and 15 per cent. ash and 1.5 per cent. sulphur. The results of the tests show that with coal, such as Pittsburg slack or run of mine, an over-all economy of 1.1 lb. per b.h.p. hour can be secured, equivalent to a little over 0.9 lb. per i.h.p. Moreover, the producer efficiency does not vary more than 10 per cent. from full load on the plant to no load.

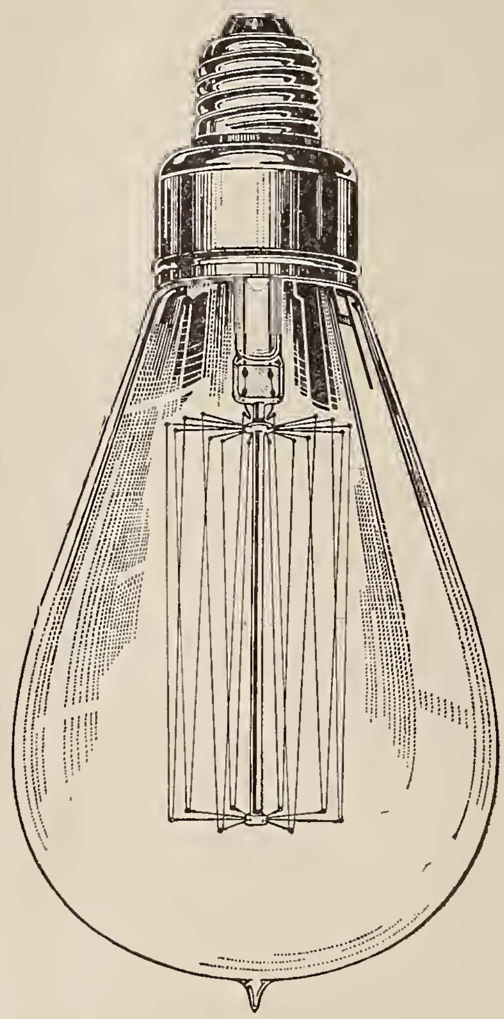
The results of this past year's tests have fully convinced the builders that the apparatus experimented with possesses unusual commercial value, and preparations are being made for extensive manufacture A plant of this type has been in operation for over six months on Colorado lignite coal with equal success, as evidenced by an order recently placed with The Westinghouse Machine Company for duplicate equipment.

The New 200-250-Volt Tungsten Lamps



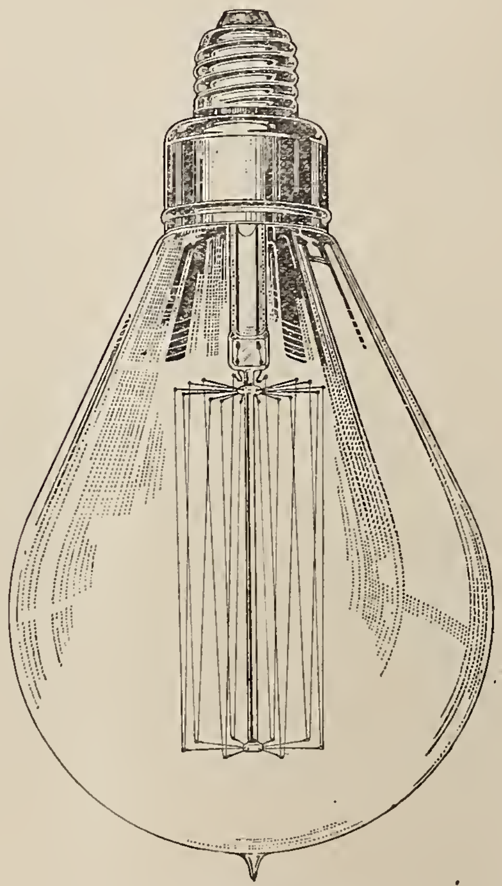
3—45-WATT LAMP.

The advantages and economy of the tungsten incandescent over the carbon filament lamp have been practically denied to most circuits operating at 200-250 volts, because the regular multiple tungsten lamps were designed for the standard voltage of 100-125. On these larger voltage circuits—for example, 220 volts—in order to use tungsten lamps at all it was necessary to operate two 110-volt lamps in series. Most users of the higher voltages preferred to wait for the advent of the tungsten adapted to their voltage.



4—70-WATT LAMP

In answer to this considerable demand the General Electric Company has extended its production of tungsten lamps into voltages from 200-250. This gives to the users of higher voltages the opportunity for the adoption of the economical high-efficiency lamps for multiple service. The regular G. E. 200-250-volt carbon filament



5—110-WATT LAMP

lamps ranged in efficiency from 3.8 w.p.c. to 3.1 w.p.c. The new tungsten has the usual tungsten efficiency of 1.25 w.p.c.

They possess all the excellent qualities of the regular G E. 100-125-volt tungsten lamps, including the same form of specially anchored filaments which make the G. E. 100-125-volt lamps so successful.

Thorough and ample tests of the new 200-250-volt tungstens show exceptionally good results, the average life and performance of these lamps being fully up to that of the standard multiple lamps. They are a decided triumph for lamp manufacture and will prove very popular with all who require 200-250-volt lamps.

The lamps are supplied in the following sizes and prices:

	Plain	Frosted
45 watt	$1.75	$1.80
70 "	2.25	2.35
110 "	2.50	2.65
180 "	3.75	3.95

These prices are subject to the same discounts as given on the regular 100-volt tungsten lamps and the same general terms of delivery.

WILKINSBURG, PA.,
EDITOR: July 17, 1909.

In Mr. W. E. Miller's article entitled "Curtis Steam Turbines for Large Power Stations," which appeared in your May, 1909, issue, are several statements so far at variance with what the engineering profession regards as fairly well established fact, that you will perhaps not take it amiss if I venture to point them out.

The first of these is the assertion that increasing the vacuum from 28 in. to 29 in. increases the available energy of steam at 200 lb. gauge pressure by 19 per cent. Unless we discredit all of the distinguished scientists whom we have looked up to as being authorities in the matter, we must admit that 9 per cent. is nearer the correct figure.

A statement that a variation of one inch in the vacuum on any turbine operating within gunshot of normal conditions can affect the coal consumption 15 per cent. is, consequently, a little too startling to be convincing.

Furthermore, we are assured that this extra inch of vacuum may be obtained without additional cost. With circulating water at 60° F., which is reasonably cold, it has been generally believed that at least twice as much circulating water would have to be pumped to maintain the temperature corresponding to 29 in. vacuum, as would be required for 28 in. Also, in order to remove the same weight of air in a given time, the volumetric displacement of the air pump would have to be 29 in. vacuum.

All other things being equal, it will be found that the cost of the additional inch of vacuum is decidedly perceptible in the way of increased cost of large condensers and auxiliaries, as well as in the increased work of the air and circulating pumps.

The effect of 11 lb. increase in initial pressure on the overall economy, is by no means a fixed quantity. With a very high initial pressure and a good vacuum, it might be a small fraction of 1 per cent.; with a low initial pressure and a poor vacuum, the percentage might run into large figures. With a vacuum of 29 inches, steam of 211 lb. initial pressure has available energy of about 3 B.t.u. per pound more than steam of 200 lb. pressure. This is approximately 1 per cent., but the author overlooked the fact that in order to generate the steam at the higher pressure, he must draw upon his coal pile for an excess of 1.4 B.t.u., so that even admitting the unusual efficiency claimed, the net result on the coal pile, in this particular case, is very modest after all.

Finally, the steam power plant that is developing a kilowatt-hour at the switchboard for 1.95 lb. of coal, considering unusual load factors, standby losses, and power absorbed by auxiliaries, is just a little too rare to be classed as "average."

Yours very truly,
EDWIN D. DREYFUS.

Western Electric Made Money in First Half of Fiscal Year

While the first half of the fiscal year of the Western Electric Co. ended with May, shows an improvement in business and an increase in sales volume far ahead of expectations six months ago, the most satisfactory element of the situation and the one upon which the officers are felicitating themselves most is the fact that the company is making money under present market conditions. An officer says:

"May 31st ended the first half of our fiscal year. Our business is running at the rate of approximately $46,000,000. This would compare with $33,000,000 for the fiscal year of 1908 and $53,000,000 for the fiscal year 1907, and the percentage relation is an improvement of 40 per cent. in the first case and at the rate of 87 per cent. of the 1907 record. The present business outlook seems to us good, but without anything to lead us to expect an unusual growth in our business. A sure and steady increase, however, may be confidently looked forward to if business conditions continue along the lines they are doing at present.

"Some lines of our business, such as our sales to the telephone companies outside of the Bell system (which have been a feature of our business for only the last year and a half), have shown a very satisfactory growth, while our business in machinery has, notwithstanding the depression, grown steadily throughout the last few years and is now at the highest point in the history of the company. Business is running more than ever before to moderate-sized motors and generators, largely used for industrial plants, which shows a healthy activity, and the prices and margins of profit at which they are being sold were never so good."

Hudson-Fulton Illumination

The illumination planned for the Hudson-Fulton celebration, Sept. 25-Oct. 9, will be the most ambitious and imposing display of lighting ever attempted. Conservative estimates place the number of lights to be used, in addition to the regular lighting of the city, at between 1,000,000 and 1,500,000 incandescents; 7,000 arc lights, 3,000 flare arcs, one battery of four searchlights of 100,000 c-p. each and one battery of 12 searchlights aggregating 1,700,000 c-p., thus making a grand total of approximately 26,260,000 c-p. This estimate may be greatly increased by electric advertising signs for which contracts for hundreds of thousands of dollars have already been made by electric lighting and display advertising firms.

This remarkable illumination is a part of the plan of the Hudson-Fulton celebration commission in charge of its illumination committee, of which the Hon. William Berri is chairman. In addition to the city illumination Mr. Berri's committee has charge of the lighting of the Hudson River Valley on the last night of the celebration, Saturday, Oct. 9th, from New York to Troy, a distance of 170 miles, with huge signal fires on mountain tops.

The Queensborough Bridge, Brooklyn Bridge, Williamsburgh Bridge, and Manhattan Bridge crossing the East River afford a magnificent opportunity for electrical display. They will be outlined from end to end by electric lights showing their graceful forms, each one differing from the other in surpassing beauty.

In Manhattan, the City Hall will be elaborately illuminated as will be the Memorial Monument at Fourth Street and Fifth Avenue, and the entire routes selected for the parades from Fourth Street up to 59th Street through Eighth Avenue to 110th Street will be lined throughout with festoons of electric lights on the curb line. It was first intended to festoon across the entire streets but the height of the floats for the historical and carnival parades has made this impossible. These festoons at all the reviewing stands will be made up of

floral garlands interspersed with electric lights and producing a very beautiful artistic effect.

Contracts for the lighting have been made with the following companies: The New York Edison, The Edison Electric Illuminating Co., of Brooklyn, The United Electric Light & Power Co., The New York and Queens Electric Light & Power Co., and the Richmond Light and Railroad Co.

The Instantaneous Nernst Lamp

The instantaneous lighting Westinghouse Nernst lamps exhibited at the Atlantic City convention of the National Electric Light Association mark another important step in the development of the glower system.

The desirable feature of lighting instantaneously is accomplished by the substitution of a new form of heater for the old platium heater. This heater becomes luminous immediately upon the passing of current and causes the glower itself to light in ten seconds thereafter.

The Nernst Company announces that on and after July 1st it will be prepared to deliver 88, 110 and 132-watt, 220-volt type A. C. and D. C. lamps equipped with the instantaneous lighting burners.

Continued Improvement of Westinghouse Business

The condition of improvement which the Westinghouse companies find their business has undergone during the past month maintain the same steady rate of advance already noted during the previous months of the present year, assuring before the close of 1909 a repetition of the busy times of 1907.

Westinghouse Air Brake Company, Wilmerding, Pa., has received a large number of orders for brake apparatus and friction draft gear. As an index of the improved conditions at the Union Switch & Signal Company, Swissvale, Pa., this plant is now employing about twice the number of men of a year ago. In June the Westinghouse Electric & Manufacturing Company, East Pittsburg, Pa., enjoyed an improvement of 25 per cent. over its business of May. A large

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NOTICE TO ADVERTISERS

Insertion of new advertisements or changes of copy cannot be guaranteed for the following issue if received later than the 15th of each month.

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EDITORIAL

LEADING ARTICLES

The Limits of Power Transmission

At the recent convention of the A. I. E. E. at the Thousand Islands, one day was largely given up to papers treating of extreme condititons met in high voltage, long-distance transmissions. While the subjects of the papers were limited to the discussion of corona effects and to regulation and output in very long lines, attention and interest are directed thereby to the question of the limits of satisfactory electrical power transmission.

Some years ago this subject was exhaustively treated in a mathematical way by Mershon (Trans. A. I. E. E., Vol. 23, p. 759), but while nothing has apparently developed to alter his conclusions, they are not in a form easily grasped without prolonged study. Mershon concluded that in a general way with the various assumptions he was obliged to make, five hundred miles was the probable limit to which power could be economically transmitted.

The limits of transmission, of course, are commercial limits, since such transmissions are invariably undertaken for profit. That is, to be successful, the enterprise must in the long run earn as great a percentage on its capital as could be earned by the same capital in other directions at the same time. In determining this matter there must be taken into account all sources of cost of whatever character.

For example, if the actual cost of the physical plant is $10,000,000 and 10 per cent. must be paid to underwriters to obtain the capital, and if on the average three years elapse between the time a dollar is put at the disposal of the construction department and the time when the money is actually expended and the corresponding element of the plant earning its full income, there must be raised a total of 10% plus 15% or 25% additional capital, making a total of $12,500,000. This is on the basis that capital is worth 5% for other uses. Returns must be reckoned on the full $12,500,000.

The gross income of the plant depends directly on the price that can be obtained for power. An approximately double expenditure for capital is permissible where power can be sold for $80 per kilowatt over the case where it can be sold only for $40, making, of course, proper allowance for variations of operating expense. The market price of power is thus of the greatest importance in determining the limit of economical transmission.

It must be borne in mind, however, that while 5% is perhaps a possibly satisfactory rate of interest where the interest earned in dividends and the principal are perfectly secure, power transmission systems by no means come in this category, and capital will usually demand the probability of a much higher rate of return. This is to cover the very material risk of partial failure, due to bad judgment in estimating the returns, bad design of plant, bad execution, or events which could not be foreseen and guarded against. Such might be the discovery of coal near a mining camp where high-priced power was sold from an expensive plant, or where legislation limited the earnings in some manner.

The factor determining the selling price of power will be usually the cost of otherwise producing it, taking into account all favorable or unfavorable collateral conditions in each case. As, for example, the supply of current to a mining camp which, at the most, can have only a limited life. Any plant installed on this spot will have to be later abandoned.

In actual practice power under the most favorable steam conditions can be generated for something like ½ cent per kilowatt, taking into account all charges and assuming approximately a 50% load factor. In other cases the price of power, especially in small quantities, may run up to 2 cents a kilowatt-hour for 24-hour service.

From the gross income must be subtracted the operating expenses and fixed charges. In a hydroelectric plant the latter mainly determines the total charges—in a steam plant they may be somewhere near half.

The fixed charges depending on the capital used depend upon two elements, the generating and receiving portion of the system, which is pretty well fixed—independent of the length of transmission and the cost of the line itself, which is directly proportional to the length, other things being equal.

The former is pretty well fixed by circumstances and ranges from $125 kilowatt delivered up to double or higher. The cost of the line must not exceed the difference between the allowable total cost and the cost of the rest of the plant, taking into account the operating expenses.

In actual large systems the cost of a double transmission line, such as will usually be used in very long systems, will run somewhere about $3,500 to $5,000 a mile without copper, depending on voltage and other conditions. This much is relatively fixed regardless of the power actually transmitted. The size conductor to have a copper cost to equal this cost must be at least as large as No. 0000 at 16 cents, so that it is clear that the cost of the transmission line is by no means proportional to the power transmitted, even at the same voltage, and will vary greatly with varying voltage. Thus, for long transmissions, large power output per line is of the greatest importance.

But a limit of capacity is soon

reached at constant voltage. With 60-cycle plants the drop with *low-lagging power factor* is very little reduced by increasing the size of copper beyond No. 0000. This is because the drop is then determined largely by the inductance of the line and is little affected by reducing the resistance. At unity power factor, however, the same condition is not reached until something like a 500,000 cm. cable is used.

With 25 cycles the same condition would be ultimately encountered, but the large sizes of wire would become earlier unwieldy.

The most important element affecting the capacity of the transmission line is the voltage, which is effective as the square. Fortunately, the cost of the line structure, exclusive of copper, is not very greatly affected by voltage until the very highest practicable limits are reached. The conclusion from this is that transmission voltages should be set at the highest reasonable values.

The limit of voltage is not one of cost, but of insulation, 100,000 to 125,000 seems now to be the utmost commercial limit; there is no good reason, however, for expecting this limit to remain fixed. As an example, we may assume a hydroelectric development in which the generating and receiving apparatus represent an expenditure of $250 a kilowatt delivered and that the 24-hr. power selling price is ½ cent per kilowatt-hour, $45 a year approximately. If the operating expenses are $15, this will permit 8% on an investment of about $375 a delivered kilowatt. If the line costs $5,000 a single circuit per mile and carries 50,000 kw., the cost per kilowatt mile is 1/5c. and theoretically the transmission could be carried 625 miles. If the line carried only 25,000 kw. the length to be reached economically would be only 300 miles about.

The paper on corona effect by Mordy covers an experimental study of the possible limitations of voltage, especially in connection with apparatus and high-tension wiring, due to corona or brush discharge, and thus has a very direct bearing on the line voltage limit. The papers of Thomas have chiefly to do with methods of securing satisfactory regulation and obtaining the maximum line output. It is probable that regulation is not a determining factor in these transmissions.

The limits of voltage on the line are the electrical strength of the insulators and the direct loss of energy into the air. The latter condition has so far never limited commercial voltages. The limits of capacity of long, very high voltage lines is very great, being theoretically up to 50,000 to 80,000 kw. at 150,000 volts.

There is another possible limit to the feasibility of very long systems, which may, though probably will not, determine the limits. This is the great danger of interruption in such very long lines and the further difficulty of controlling the enormous amounts of power involved and of automatically clearing trouble and of starting after a shut-down.

From this discussion it would be clear that the maximum limits of transmission for any given set of conditions can be quite readily approximated, using easily estimated figures of unit costs and the selling prices of power. Further then, it is clear that it is not practicable to give any satisfactory general limiting distances. Mershon has done about all that is feasible in this direction.

There is another condition usually present in actual experience, which greatly advances the commercial economy of very large, long-distance systems; namely, that in such systems there usually are a number of sources of power more or less widely distributed and a larger number of points where load is delivered. Very little power is ever transmitted over the whole length of the line. The system then becomes a distributing and usually a collecting system for electric power, as well as a transmission system. The California Gas & Electric Company's system is perhaps the best-known example of this type.

With the development of railroad electrification, other examples will undoubtedly appear.

The Turbine Has Arrived

The large manufacturers have at last reached a point where the steam turbine department has commenced to show a penny on the credit side of the ledger. Many articles have appeared in the technical press for two or three years past stating that the turbine as a prime mover had arrived. While the turbine as a machine had arrived, it was far from having arrived as a commercial proposition to the manufaeturer. Even the later successful plants required so many minor changes all profit was eaten up many times over. A great deal of what would have been profit has been eaten up in improvements which have hastened the day when the manufacturer could install a plant and then forget about it, exeept for the pleasure of showing it to prospective buyers of like equipment.

For about a year back the forgetable plant has been in use and the makers have begun to find the depth of the bottomless pit of expense which seemed to go with the development stages of the turbine. These experimental and development eosts have probably been relatively no greater than like ones for other machines. But, as the turbine has been developed for commercial use in one-fifth the time it has required for other types, the cost has been condensed into a shorter period. Only big institutions, solid financially, have made possible the rapid introduction of this device.

Now that the standards have been secured the future development will probably be in details only. There is still much work to do in the sizes from about 300 kw. down.

The ordinary small turbine of from 25 to 250 kw. requires condensing about 30 to 35 lb. of steam per horsepower hour. These figures change to 60 to 70 when operated non-condensing. It is evident that a big field awaits the inventor, or company, who can bring out a small non-condensing turbine with reasonable steam economy.

"Some Recent Developments in Electrical Apparatus," by E. W. Allen, is worthy of close reading because it discloses that the design of electrical machinery, which for some years prior to the advent of the steam turbine had fallen into a period of somnolence, has begun rapidly to change again.

The most important thing noted by Mr. Allen is, perhaps, the redesigning of direct-current machines for the high speeds of turbine drive. Long commutators of relatively small diameter as compared with the present design, and the adoption of the auxiliary pole to maintain the present excellence of commutation are the chief changes to be noted.

The vertical rotary converter, which the author avers in one instance has increased a substation output by 50% over that possible with any other type of machine, is certain to attract much attention, since its use in new stations indicates a saving in the ground plot and a slight reduction in the cost of the substation structure.

Reliability in the automatic switching of station loads by remote control is another topic which is only slightly touched upon in this article. It is, however, one of the big essentials in putting electric power transmission on a surer footing with public favor. Some of us still remember the early days of transmitting current for lighting, when one attendant kept his eye between the purring machine and the crude switchboard, while another patrolled the arc lamp lines with a wooden stiek, ready to argue with reealcitrant arc lamps or meddlesome strangers.

Some Recent Developments in Electrical Apparatus

E. W. ALLEN

The uses of electricity are so varied that a record of the development in all branches of the industry must of necessity be the work of many writers, and if confined to the limits of this paper would prevent a complete exposition of the progress in any line of manufacture. It is, therefore, my intention in presenting this paper to consider only some of the more recent developments in the design and construction of generating, converting and controlling apparatus of the types ordinarily found in modern central station practice. While many of these developments will be recognized as the natural result of evolution and others as the application of well-known principles to new conditions, they will, it is hoped, serve to indicate the progress that has been made in the development, manufacture and use of electrical machinery*

GENERATING APPARATUS

The general acceptance of the steam turbine as a prime mover of electric generators marks an epoch in the progress of their development. Prior to its introduction, limitations in the speed of prime movers, particularly reciprocating engines, placed certain restrictions upon the designing engineer which resulted in a machine of larger diameter, small output per pound of material and high cost of manufacture.

Alternating-current generators for direct connection to steam turbines have been developed in larger capacities than direct-current machines, and for this class of work represent a more important branch of the industry.

Alternating-Current Generators.

The revolving-field generator illustrated in Fig. 1, may be described as a 14,000-kw., 6600-volt, 60-cycle, 3-phase alternator suitable for direct connection to a vertical-shaft steam turbine of the Curtis type operating at a speed of 720 revolutions per minute.

The novelty in the electrical design of this machine is due to the high speed of rotation. Broadly speaking, the amount of copper and magnetic material are inverse functions, respectively, of the kilowatt output per pole and the peripheral speed of the revolving field. The machine under discussion has a peripheral speed of 18,300 feet per minute and an output per pole of 1400 kw., as contrasted with a peripheral speed of 8000 ft. per minute and an output of 150 kw. per pole in an engine-driven alternator of the same capacity and frequency operating at 75 rev. per min. The result of this high speed is the production of a generator of small diameter, large output per pound of material, and consequently smaller radiating surface to dissipate the heat due to the internal losses; although the mechanical difficulties encountered in the design of these large machines make it impracticable to obtain so great a reduction in cost as we might expect from a comparison of its speed with that of a machine of the same capacity operating at a speed suited to reciprocating engines.

The electrical and magnetic losses in the field and armature of a 14,000 kw. generator amount to approximately 350 kw. This loss for a period of one hour is equal to 1,195,000 B.t.u., and is equivalent to the heat generated in the furnace of a 35-h.p. boiler for the same period of time. To conduct this heat away from the generator without permitting local high temperatures requires about 40,000 cu. ft. of air per minute at usual room temperatures.

In order to control the movement of air the generator is totally enclosed, with the exception of the intake and discharge openings at the top and bottom of the armature. When the machine is running the revolving field acts as a powerful fan, receiving air through the opening in the ventilating hood, forcing it through passages provided for this purpose in the field and armature, and discharging it through the opening at the bottom of the generator. This method of ventilation, while well suited to large generators, does not apply to all sizes, and other means will be found desirable in smaller high-speed machines.

Direct-Current Generators.

Direct-current commutating machines as usually applied are unsuited to the high voltages required for the production of power in large quantities and its distribution over wide areas from a central station. As a result we find to-day that most of the direct current used is derived either from machines which form part of high-speed motor-generator sets or synchronous converters with step-down transformers, receiving high-voltage alternating current and delivering direct current at relatively low voltages.

Many recent developments in direct-current machines have been attended by high speeds of rotation that required long commutators of small diameter and consequently unsuited to the construction generally used in slow-speed machines, in which dovetailed bars were clamped or bound to an insulated drum by means of compression plates on the inner surface of the assembled commutator. In the construction finally adopted for high-speed machines the bars are held in place by steel rings shrunk over the outer circumference of the commutator, and the necessity of compression plates and specially machined bars is thereby avoided. The advantages claimed for this design are great mechanical strength and surfaces that can be readily insulated due to the plain shape of the bars. The difficulties encountered in the electrical design resulting from the high frequency of commutation have been overcome by the adoption of auxiliary commutating poles installed between the main field poles of the generator.

The design of belt-driven generators has probably been subjected to more noticeable changes than that of any other type of direct-current machine. The demands of the purchaser require a moderate-speed machine having low cost and good operating characteristics, while the requirements of the manufacturer demand a machine of few parts, interchangeable as motor or generator, and readily converted into a partially or totally enclosed frame. The result of these demands has been the production of a generator that could by a change in the field coils be converted into a constant or variable-speed motor, suitable for machine-tool work. The mechanical design permits it to be mounted on the floor, wall or ceiling by changing the position of the end shields supporting the bearing, and converted into a semi or totally enclosed frame by the addition of perforated or solid covers to the openings provided therefor in the end shields.

The efficiency of direct-current generators offers more room for improvement at fractional load than at full load, and in this respect the new machines are materially better than the old standards.

In developing this machine full advantage has been taken of the benefits to be derived from the use of commutating poles in securing successful commutation without movement of the brushes for all values of load within the limits of the rating. Particular attention has also been given to the ventilation and to assisting the movement of air through the field and commutator by means of a fan mounted on the shaft at the end of the armature opposite the commu-

*N. E. L. A., 1909.

tator. The compactness of the design is clearly illustrated by Fig. 2, which shows a 35-kw., 250-volt generator of the new design.

CONVERTING AND TRANSFORMING APPARATUS

The use of converting and transforming apparatus began with the introduction of alternating-current generators. In the smaller systems of distribution the transformer capacity is from 50 to 75 per cent. greater than that of the generator apparatus, while in many of the larger systems the combined capacity of converting and transforming machinery is approximately three times as great as that of the generators. The extent and variety of its manufacture constitutes, therefore, an important branch of the electrical industry and one in which we may rightly look for many new developments. A review of the field confirms our expectations.

Converting Apparatus.

Synchronous converters, or as they are more commonly termed, rotary converters, have, on account of their high efficiency and low first cost, become the standard form of converting apparatus for low-frequency substations. Heretofore wide ranges in the direct-current voltage have been obtained by the use of induction regulators or series boosters installed between the transformers and the alternating-current side of the rotary, but in recent designs wide ranges in the direct-current voltage have been obtained without resorting to external devices by the installation of regulating poles between the main poles.

This means of controlling the direct-current voltage is radically different from anything heretofore employed and represents the latest and most important advance that has been made in the art of manufacturing this particular class of apparatus. In any synchronous converter the direct-current voltage has a definite value or ratio with respect to the alternating-current voltage impressed upon the collector rings, which ratio can be varied within certain limits by changing the width of the pole arc. The function* of the regulating pole is to vary the width of the arc and hence the ratio of alternating to direct-current e.m.f. by assisting or opposing the flux in the main pole. The general appearance of this machine is shown in Figs. 3 and 4.

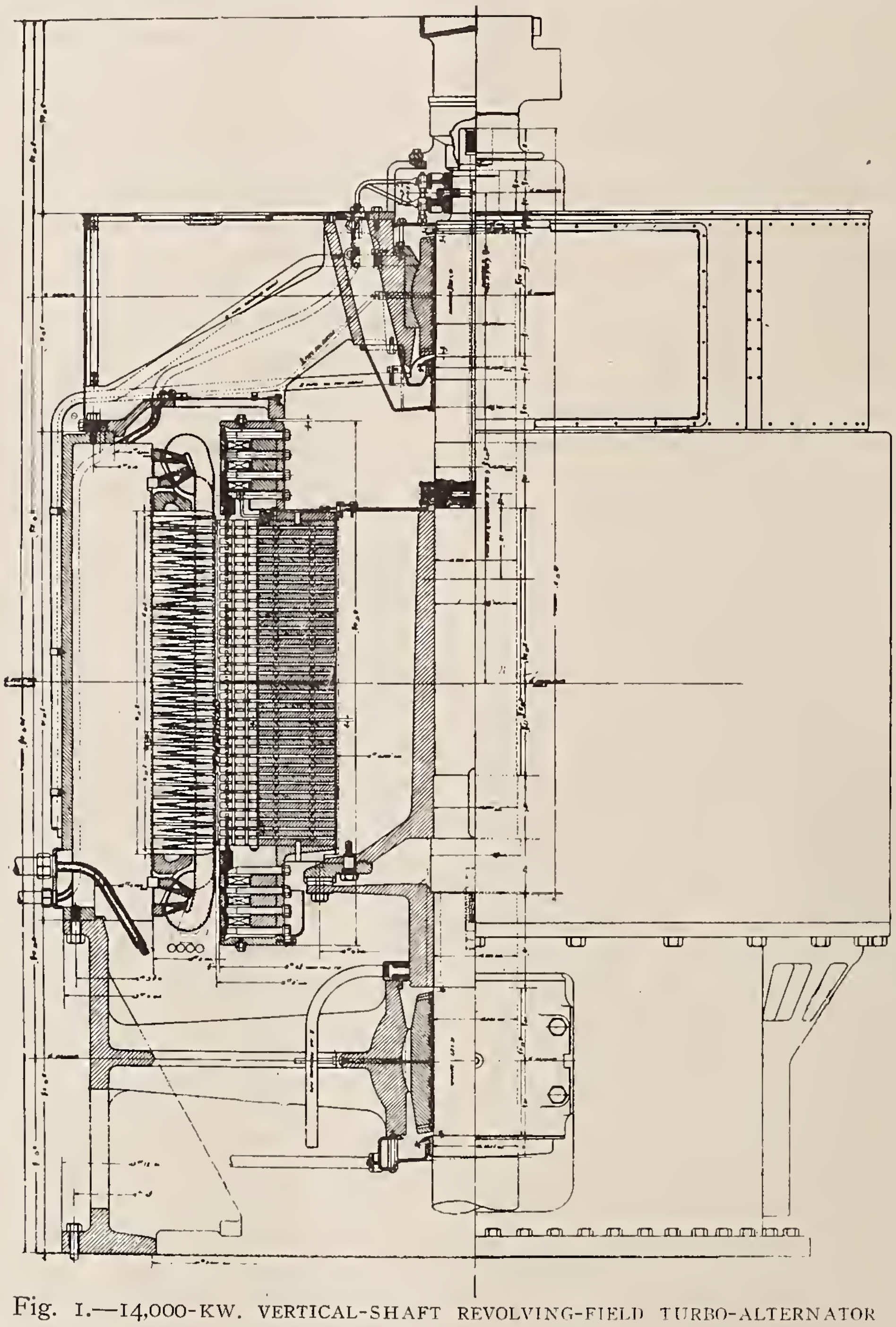


Fig. 1.—14,000-KW. VERTICAL-SHAFT REVOLVING-FIELD TURBO-ALTERNATOR

The excitation of this type of converter can be controlled by means of an automatic regulator, and the direct-current voltage kept constant even with wide variations in the voltage of the alternating-current supply. The regulator may also be adjusted to hold a constant load on the converter and cause storage batteries or other machines to carry fluctuations in the load beyond a predetermined amount. Advantage can be taken of this point when the power is purchased from a transmission line and the rate of charge based on the maximum demand.

Variable ratio converters are particularly well suited for installation in substations receiving alternating current at high voltages and delivering direct current to 125/250-volt Edison three-wire systems, supplying a lighting load or a mixed lighting and power load.

It is often necessary to increase the output of substations having limited floor space and head room, by the installation of larger units. Instances of this kind are found in substations located in the basement of office buildings in large cities. The conditions here imposed have been successfully met by a vertical synchronous converter of novel design, as illustrated in Fig. 5. In one case with which the writer is familiar, the use of this machine permitted the output of a substation to be increased 50 per cent. over that possible with any other machine available.

There are now in process of manufacture several 2500-kw., 250-volt, 25-cycle, six-phase converters of the vertical-shaft design for the New York Edison Company, which, in point of output will represent when completed the largest synchronous converter ever produced.

Frequency-Changer Sets.

The purpose of a frequency-changer set is apparent from the name. When exact changes in frequency are required from them the generator and motor that form the set must both be synchronous machines, and the speed of the set being dependent upon the ratio of their frequencies, must obviously be a speed common to both frequencies, and in a 25 to 60-cycle set can never exceed 300 rev. per min. If the frequency of the generator is not fixed by the distributing system to which it is connected, and

*Transactions American Institute of Electrical Engineers, 1908, *Voltage Ratio in Synchronous Converters, with Special Reference to the Split-Pole Converter,* by Comfort A. Adams; General Electric *Review,* Nov., 1908. *Variable Ratio Converters,* by C. P. Steinmetz.

can be varied within certain limits, the motor end of the set may be non-synchronous, or of the induction type. When the rate of charge is based on the maximum demand after the manner described for the regulating pole converter, the load taken from a transmission line by an induction motor-driven set can be automatically controlled by varying the resistance in the windings on the rotor of the induction machine.

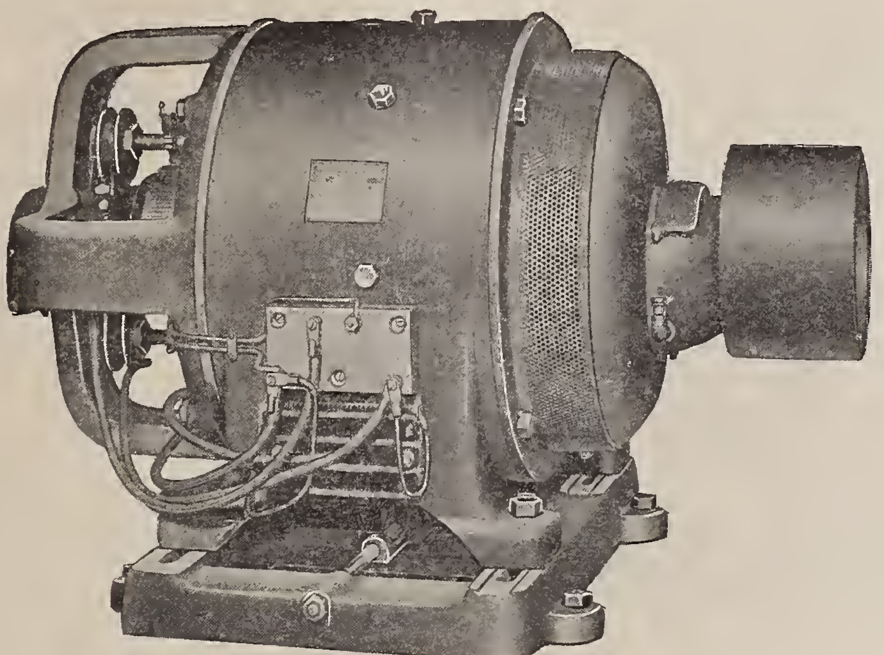


Fig. 2.—35-KW. DIRECT-CURRENT GENERATOR—GENERAL ELECTRIC CO.

The electrical design of these sets affords little opportunity for improvement beyond that found in standard alternating current generators and motors, but the mechanical design presents an opportunity for using several different methods of supporting the revolving member. The vertical-shaft construction, by virtue of the saving in floor space, ease in assembling and balancing, reduction in weight and starting current, and symmetry of outline gained by its use, has recently been adopted for these sets in capacities above and including 2000 kw. In the first machines built, the revolving member was supported on an oil step-bearing of the type used in steam turbines, but in the most recent designs a roller step-bearing has been used with great success. The general appearance of a 2000-kw., 25 to 60-cycle, vertical-shaft set of this design is shown in Fig. 6.

It may be of interest to record here the manufacture of a 6666-kilovolt-ampere, 0.75-power factor, 25 to 60-cycle set of the same design as that illustrated. When completed this unit will in point of output be the largest yet produced and will be installed in one of the stations of the Commonwealth Edison Company at Chicago,

Transformers.

Progress in the development of static transformers can in most instances be characterized by the improvements in the methods of cooling. The losses in proportion to the rating are less in transformers than in almost any other class of electrical apparatus, but the heat resulting therefrom is confined in a space that does not possess sufficient radiating surface to dissipate the heat without injuring the insulation unless artificial means is provided for conducting this heat away from the core and coils in which it is generated. Oil is the medium most generally used for this purpose. In the smaller sizes the natural circulation of oil through the core and coils is relied upon to conduct the heat away and the transformer tank has in turn sufficient radiating surface to cool the oil. As the capacity increases these conditions no longer hold, for the output varies approximately in proportion to the weight, or third power of the linear dimensions, while the radiating surface varies only as the second power of the linear dimensions. This condition, therefore, requires artificial means for cooling the oil, as evidenced by the standard designs with cooling coils located in the upper part of the oil tank.

In very large units the circulation of the oil through the ducts provided therefor in the core and windings and around the cooling coils is forced by some external means, and, in contrast to the standard design mentioned above, the cooling coils are located not only at the top, but throughout the entire distance from the top to the bottom of the tank. An auxiliary shield or baffler directs the movement of the heated oil and prevents it reaching the core and windings until it has been cooled. When the transformer is carrying load the heated oil is drawn from above the core and windings and discharged over the cooling coils by means of a motor-driven centrifugal pump, located on top of the tank, as shown in Fig. 7.

This improvement in the method of circulating the oil, by providing a more efficient means of conducting the heat from the seat of its generation, has enabled a material reduction to

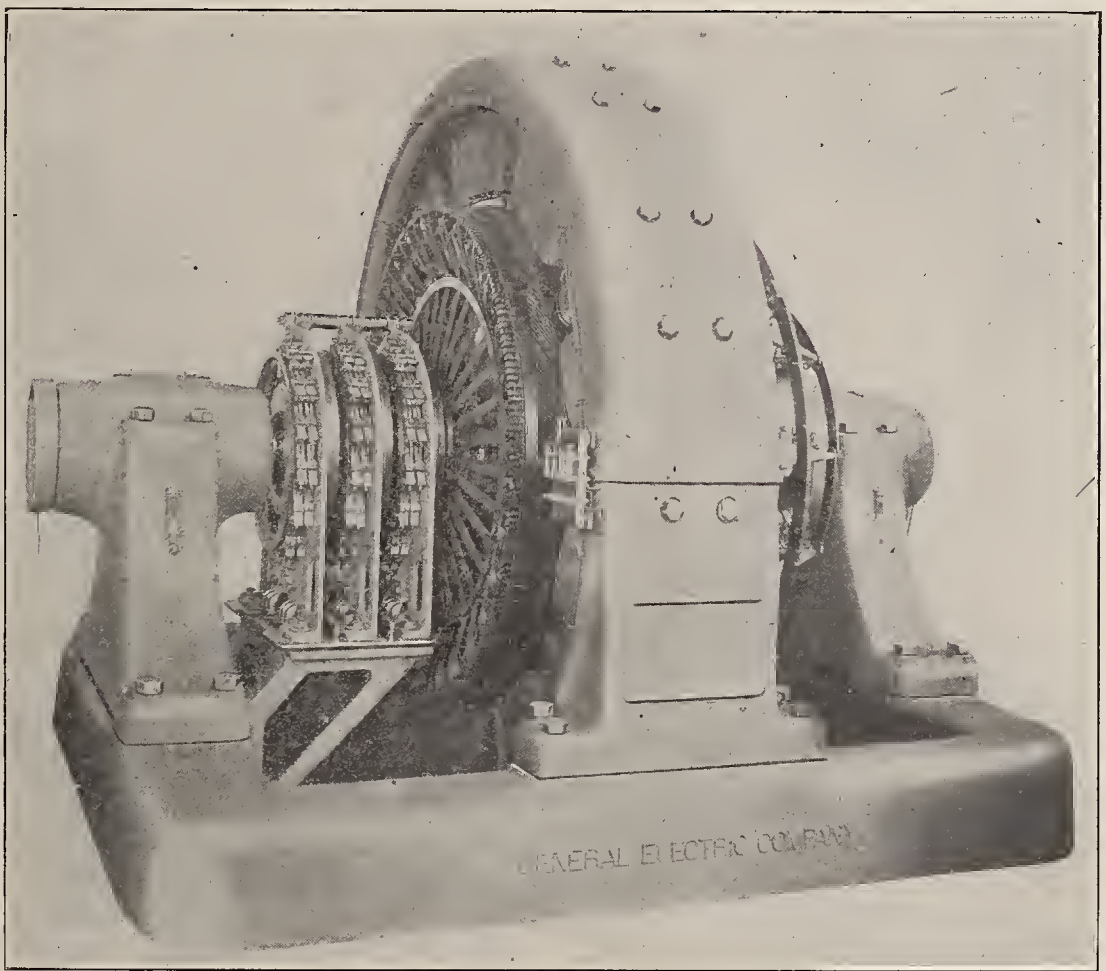


Fig. 3.—1000-KW. REGULATING-POLE SYNCHRONOUS CONVERTER—COLLECTOR END

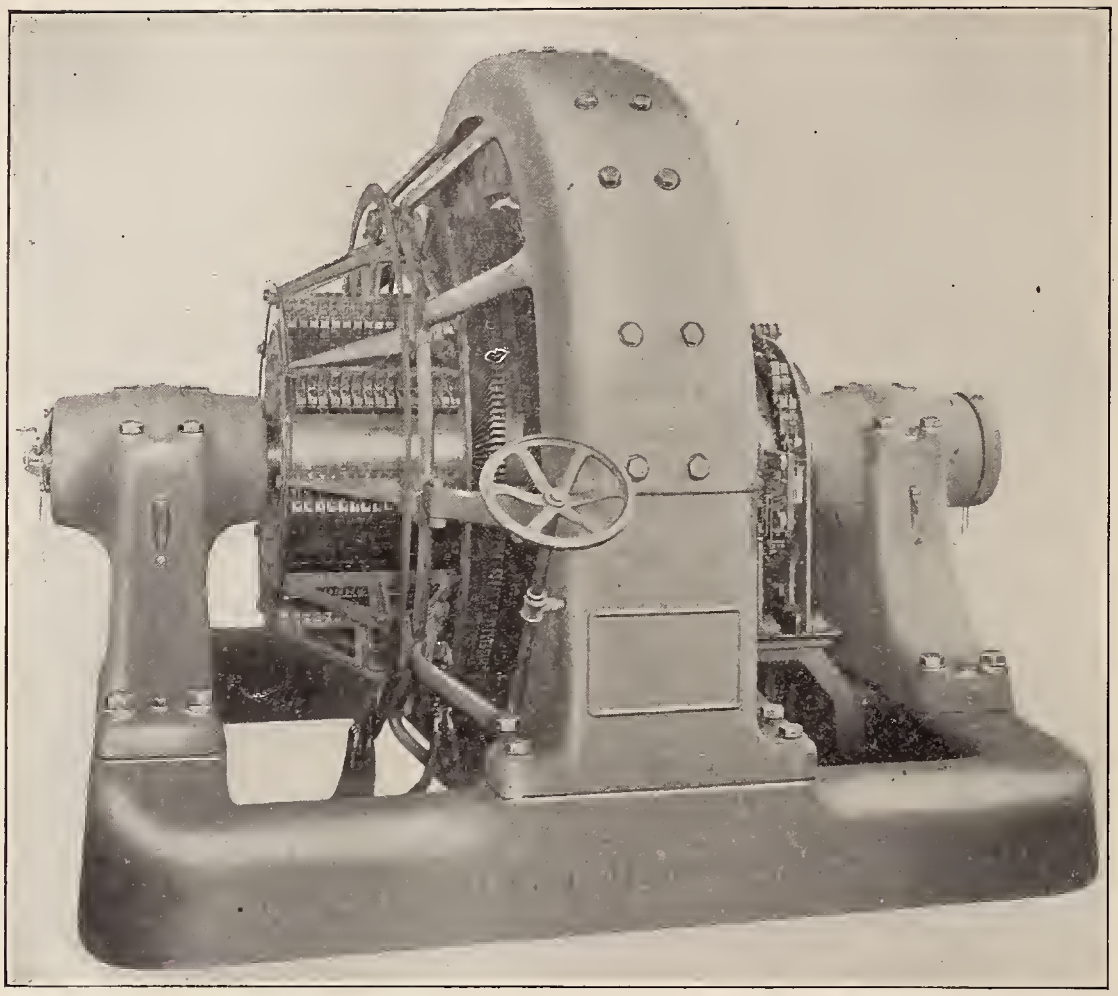


Fig. 4.—1000-KW. REGULATING-POLE SYNCHRONOUS CONVERTER—COMMUTATOR END

be made in the weight, floor space and efficiency of the transformer.

CONTROLLING AND PROTECTING APPARATUS

Improvements in the design of the controlling and protecting devices have contributed in a large degree to the progress that has attended the electrical industry. It has been said that machines could be built and operated without employing any form of controlling, indicating or protecting devices, but if the possibility of this condition is granted no limit must be admitted to the refinement that may be gained by their use.

Controlling Apparatus.

Increase in the capacity and area of distributing systems has been accompanied by the use of many automatic and remotely controlled switching devices. When they are used the extent and importance of the trouble due to their failure must be anticipated and provided for in some measure. Recent developments have, therefore, been largely confined to improvements in the reliability of the automatic features and methods of control from places remote from the point of installation, but their design can not in the strictest definition of the word be considered a recent development, although the general application of electrically operated switching devices to controlling systems may properly be so considered and will better serve the purposes of this paper. With a few notable exceptions, the following order prevailed in the application of remote-control features to oil switches, motor operation, solenoid operation and pneumatic operation.

The first method of control has been used for switches having large capacity and which naturally require relatively long movement of the contact-breaking parts. In the opening and closing of these switches the inertia of the moving parts is overcome by means of compression or torsion springs, while the motor completes the travel and stores energy in the springs for effecting the next operation.

The second method of control is well adapted to those oil switches and circuit-breakers that as a class do not require so much energy for their operation. The movement of the plunger in the solenoid is imparted to the switch mechanism by means of a toggle joint, and the length of the motion multiplied by a system of bell cranks and levers.

The third and last-named method of operation has been recently applied to very high-voltage switches of large rupturing capacity. The moving element of the switch is connected directly to the piston of an air cylinder without the use of an intermediate mechanism and may be operated by applying air pressure to this piston through suitable valves. Pneumatic operation has also been successfully applied to the control of high-tension disconnecting switches by means of a diaphragm and toggle mechanism. All three of these types are sometimes found in a single system of distribution, although each has a particular field for which it is best adapted.

In stations containing a large number of important circuits the use of these remote-control devices enables the engineer to place the switches and bus bars in fireproof compartments located without regard to the controlling board, and brings their control under the direct supervision of a single operator. The advantages gained from this arrangement are best illustrated by an example: In one substation with which the writer is familiar this method of control permitted the operator to stand at the centre of a controlling board 19 ft. long and with-

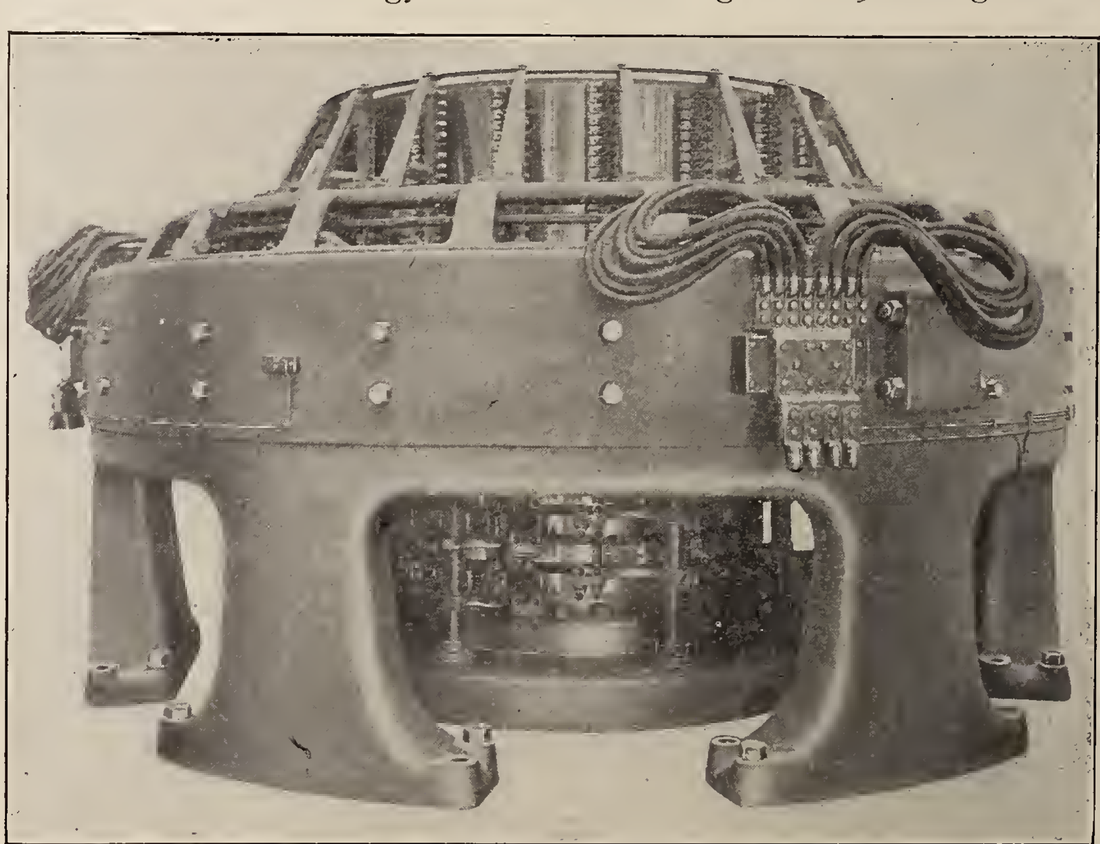


Fig. 5.—2000-KW. VERTICAL-SHAFT SYNCHRONOUS CONVERTER

out moving over eight and a half feet in either direction to operate seventeen high-voltage alternating-current circuits distributing a total of 40,000 kw. In another station, containing 3500 kw. in generating apparatus and receiving and auxiliary supply of power from a water-power transmission line, the switching devices required for the frequency-changer sets, motor generator sets and power feeders, made the ultimate length of the switchboard 75 ft., including panels already installed for the control of the steam-driven generators and commercial feeder circuits, using manually operated switches. The adoption of solenoid-operated, remote-controlled oil switches, permitted the total length of the switchboard to be reduced from 75 ft. to 30 ft., thereby bringing the entire control under the ready supervision of one attendant. Economies in the installation practically offset the increase in cost due to the addition of these features to the oil switches.

The latter installation will, it is believed, suggest some of the arrangements made possible and the economy in operation often resulting from the use in medium-sized stations of remote-controlled solenoid-operated in preference to manually-operated switching devices.

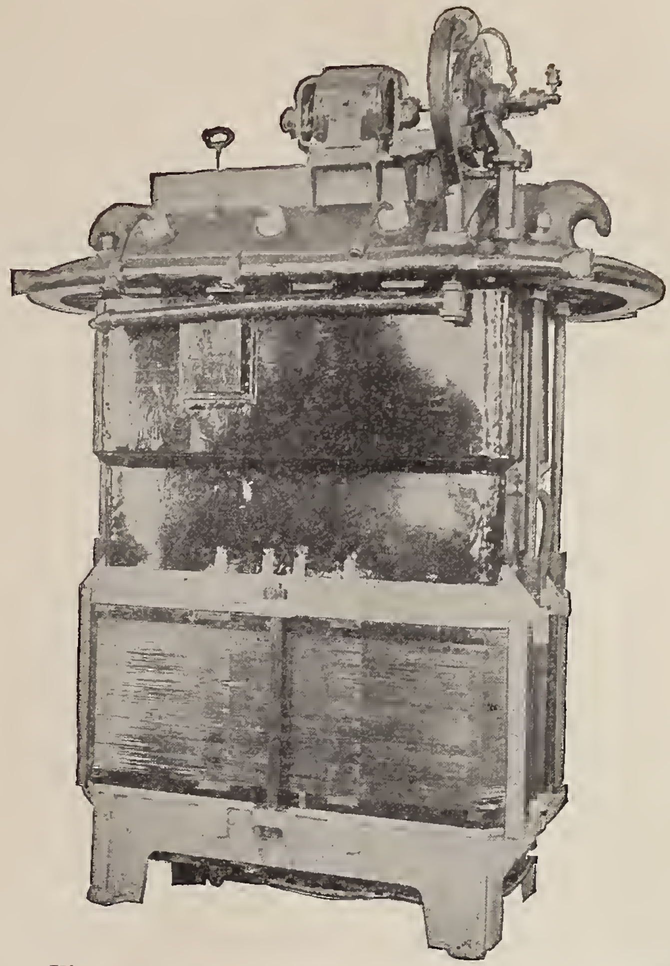


Fig. 7.—3000-KW. FORCED OIL-COOLED TRANSFORMER

PROTECTING APPARATUS

Aluminum cell lightning arresters have greatly increased the reliability of high-voltage transmission lines and may be properly termed one of the most important developments that has taken place in the design of protecting apparatus. Its construction and operation have already been described in a paper presented before your association, and it seems unnecessary, therefore, to enter into a detailed discussion of these features; but as a great number of these have been installed on transmission lines in all sections of the country it seems both timely and proper to record here their commercial status or the success with which they have been operated.

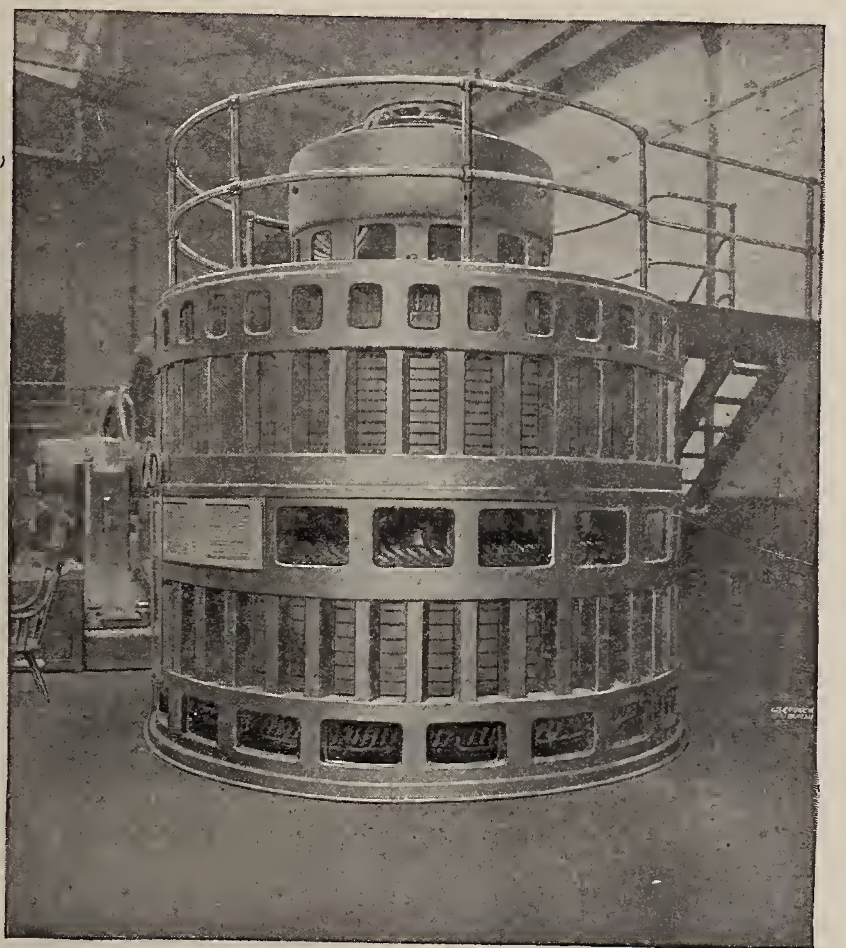


Fig. 6.—2000-KW. VERTICAL-SHAFT FREQUENCY-CHANGER SET

After these arresters had been placed in service for several years the engineers in charge of their design selected a high-voltage transmission line that traversed the mountainous district of Colorado, on which the troubles due to lightning in one form or another had become so burdensome as to affect the commercial success of the power development. Thirty or more substations were supplied by this transmission system, but aluminum-cell lightning arresters were installed in only the more important of these and the protection of the remaining substations was left to other types of arresters previously installed. A record of the shut-downs caused by lightning during the year preceding the installation of aluminum-cell lightning arresters and a record of the shut-downs from all sources, including lightning and lines troubles after their installation is given below:*

	1907	1908
Total number of electrical storms.....	34	470
Electrical storms causing complete shutdowns.....................	8	1
Electrical storms causing partial shutdowns.....................	17	2
Electrical storms causing no shutdowns.	9	44

NOTE.—The only complete shutdown in 1908 occurred at a station unprotected by an arrester.

The results of its performance on such circuits have led the manufacturers of this arrester to adopt and recommend it as their standard device for all classes of high-voltage transmission lines.

*_Transactions_ Colorado Electric Light, Power and Railway Association, _Lightning Arrester Protection and Equipment on the Animas Power and Water Company System,_ by J. A. Clay.

The Principles of Illumination

Electric lighting may be classified according to whether it is used for ordinary illumination, or for such special purposes as stage lighting, projectors, advertising, etc. The scope of this article includes only ordinary illumination.

AMOUNT OF ILLUMINATION

The eye is capable of perceiving a *difference of illumination* of slightly less than 1 per cent. when two illuminated surfaces are viewed in juxtaposition. This sensitiveness does not vary greatly with the absolute illumination,* but is probably a maximum at an illumination of about one or two candle-feet.

The *power of recognizing fine detail* follows a different law. It increases very rapidly with the illumination up to about one candle-foot. Between one and two candle-feet, the visual acuity increases less rapidly and above two candle-feet, increases very slowly. The illumination referred to above is that available to the eyes and not that which falls on the illuminated surfaces.

The illumination which reaches the eyes (E) equals the surface illumination x co-efficient of reflection (k).

Except for very fine type, drafting, or other special cases, E may be as low as 1.50 candle-feet.

LIBRARY ILLUMINATION.
(E. F. Legg and H. I. Townsend, *Elect. World*, Feb. 1, 1908.)

	Candle-feet Night	Day
State Historical Library, Madison, Wis. 1.30 P.M. clear day in May	3.5	5.5
Milwaukee Public Library, cloudy day in February	1.6	11.8
Chicago Public Library, clear day, 3.30 P.M	1.67	21.0
Newberry Library, Chicago, noon, cloudy day in February	1.65	35.0
John Crerar Library, Chicago	1.48	5.3
Average	1.98	15.7

Where table lamps are used the general illumination additional to these should be between 0.3 and 0.5 candle-foot with dull finish walls.

Franklin & Esty's "Elements of Electrical Engineering" states that the intensity of illumination required for easy reading is one candle foot or 12.21 luxes.

ILLUMINATION.
From Das Hilfsbuch der Allgemeinen-Electricitäts-Gesellschaft.

	Hefner Candles per sq. meter of floor.	English candles per sq. of floor.
DWELLING HOUSES:		
Reception rooms	4–5	.33–.41
Living and dining-rooms	3–3.5	.25–.29
Bedrooms	1.5–2	.12–.17
Passages, etc	1–2	.08–.17
OFFICES:		
Principal rooms	5–6	.41–.49
Less important rooms	2–2.5	.17–.20
Private offices	1.5–3	.12–.25
SHOPS AND STORES		
Shops and showrooms	4–7	.33–.57
Office and storerooms	2–2.5	.17–.20
HOTELS:		
Banqueting rooms	9–13	.74–1.1
Public rooms	5–7	.41–.57
Best bedrooms	3.4	.25–.33
Ordinary bedrooms	2–3	.17–.25
Passages	1–1.5	.08–.12
Kitchens, etc	1–2	.08–.17

*Fechner's Law.

For shop-window lighting, three to six lamps per meter or one to two lamps per foot of window frontage.

EFFECT OF REFLECTION

The illumination due to a source of light is increased greatly by reflection from wall surfaces, etc. In an ordinary room, where the light is irregularly reflected from wall to wall, the direct illumination is increased in the following ratio:

$$\text{Illumination} = \frac{1}{1-k} \text{ by illumination without reflection.}$$

k = proportion of incident light reflected from a single surface. Values of k, and $\frac{1}{1-k}$ for various surfaces, and values of $\frac{1}{1-k}$ for various values of k are given in the following tables:

APPROXIMATE COEFFICIENTS OF REFLECTION.

Material	K	$\frac{1}{1\ K}$
Polished silver	.93	14.3
Mirror, silvered	.85	6.66
White paper, cartridge	.80	5.0
Mirror, amalgam	.70	3.33
White foolscap paper	.70	3.33
Orange paper	.50	2.0
Yellow paper	.40	1.66
Light pink paper	.35	1.53
Light blue paper	.25	1.33
Emerald green paper	.18	1.22
Dark brown paper	.10	1.11
Black paper	.05	1.05
Black velvet	.004	1.005

The quantity $\frac{1}{1-k}$ seldom exceeds 1.5 in a room.

It should be noted that a diffusing reflector like white paper is practically as efficient as a mirror.

REFLECTION FROM WALL PAPERS.

Kind	Color	K Coefficient of Reflection Sky-light	Incandescent Lamps
Plain Ceiling	Faint greenish	.50	.53
	Light ecru	.27	.26
	Very faint grey cream	.53	.64
	Light grey green	.26	.23
	Light yellow	.53	.49
	Faint ecru	.47	.55
	Faint pinkish	.41	.43
	Pale bluish white	.42	.31
Crepe	Medium green	.25	.19
	Darkish coffee brown	.08	.66
	Deep green	.05	.16
	Deep yellow buff	.41	.08
	Full green	.06	168
	Deep red	.05	.45
	Medium red	.06	.08
Cartridge	Medium green	.15	.03
	Dull green	.11	.07
	Dull yellowish green	.09	.07
Cartridge	Light pinkish brown	.21	.26
	Light green	.23	.18
	Light blue	.21	.20
	Pale grey	.35	.27
	Faint yellowish green grey	.43	.33
	Salmon buff	.31	.33
	Meidum light buff	.44	.34
	Medium full green	.11	.07
	Medium dull red	.06	.07
	Light red	.10	.10
	Very deep ecru	.18	.15
	Pale pink	.25	.19
	Deep yellow grey	.18	.15
Silky Finish	Medium crimson	.08	.12
	Medium grey green	.17	.12
Stripes	Deep cream	.56	.60
	Deep cream silvery	.56	.57

Kind	Color	K Coefficient of Reflection Sky-light	Incandescent Lamp
	Yellow medium	.50	.53
	Deep buff	.53	.58
Stripes	Medium red	.06	.08
	Medium red satin	.07	.11
	Light strawberry pink	.43	.43
	Light strawberry, silvery	.51	.49
	Light and dark green	.06	.07
	Silvery light green	.13	.14
	Light green	.36	.26
	Silvery light green	.36	.23
Miscellaneous	Dark green and gold	.24	.19
	Light green and gold	.31	.28
	Deep and light red	.12	.20
Piqué	Light bluish	.46	.47
	Light grey	.38	.38

(Angle of incidence about 35° to 45° L. Bell (Illuminating Eng. Soc. Transac., Oct., 1907. Illuminating Engineer, Jan. 1908).

VALUES OF $\frac{1}{1-K}$

K	$\frac{1}{1-K}$
.95	20
.90	10
.85	6.66
.80	5.00
.75	4.00
.70	3.33
.65	2.85
.60	2.50
.55	2.22
.50	2.00
.45	1.81
.40	1.66
.35	1.53
.30	1.42
.25	1.33
.20	1.25
.15	1.17
.10	1.11
.05	1.05

KIND OF ILLUMINATION.

Illumination may differ in *color,* and *"softness."*

White light is essential for correct *color-matching,* but colored lights are useful where this feature is unimportant.

The effect of light on colors is shown by the following table. Every opaque object assumes a color due to the sum of the colors it reflects.

Reddish and yellowish lights are *warm* and are popular because they intensify flesh tints. Bluish lights are *cold* and unsuitable for house illumination on account of the unpleasant pallor they produce

COMPOSITION OF LIGHTS.
ABNEY'S TESTS.

	Sun	Sky	Arc	Gas
Red	100	100	100	100
Green	193	256	203	95
Violet	228	760	250	27

The component colors of lights are usually referred to as Fraunhofer's lines, which are the black lines in the spectrum of the sun.

The approximate locations of these lines are:

A, Red (deep).
B, Red.
C, Orange.
D, Yellow.
E, Green.
b, Green (bluish).
F, Blue.
G, Indigo.
H, Violet.

DETAIL DISCRIMINATION.

We are virtually near-sighted for

the violet end of the spectrum. Therefore while violet light is usually somewhat better than white light for the illumination of detail at close range, it is very bad for the illumination of distant objects. Red, on the other hand, is usually best for the illumination of distant objects.

CHROMATIC ABERRATION.

As rays of different colors are unequally refracted, the eye cannot focus more than one color perfectly at a time. Hench white light is inferior to mono-chromatic light for detail discrimination. This accounts for the popularity of mercury-vapor and other mono-chromatic lights for draughting rooms, machine shops, garages, etc.

By the *"softness"* of illumination we mean the absence of sharp contrasts of illumination. Softness is regulated by the use of shades, reflectors, and by the proper distribution of lights.

ABSORPTION BY SHADES.

Kind of Glass	For Arc Lamps (a)	For Incandescent Lamps (b)
Clear	10	..
Holophane	12	..
Alabaster	15	..
Prismatic	..	20.7
Opaline	20–40	23
Ground	25–30	24.4
Opal	25–60	32.2
Milky	30–60	..

(a) L. Bell. (b) W. L. Smith.

Holophane globes are designed for downward, equal or outward distribution and while diffusing the light well, absorb little more than clear glass provided they are clean. If dust is allowed to accumulate on them, they are of course inefficient. The holophane shade is grooved horizontally so as to form a series of annular prisms.

Ordinary cut-glass shades should be avoided as they do not diffuse properly. Streaked and mottled shades are bad for the same reason.

Light thrown up to the ceiling and reflected down is well diffused and softened, but is apt to eliminate shadows. Hence where this kind of illumination is adopted, the lights should be at the side of the room. With this precaution, lighting by ceiling reflection is practically perfect.

Ceiling reflection may be realized by arc lamps with large reflectors underneath or by a line of incandescent lamps with reflectors underneath, the lamps in the latter case being ranged along a cornice, or cove.

Color of Fabric in white light.	Color of Light					
	Red	Orange	Yellow	Green	Blue	Violet
White	Red	Orange	Yellow	Green	Blue	Violet
Red	Intense Red	Scarlet	Orange	Brown	Violet	Purple
Orange	Orange Red	Intense Orange	Yellow Orange	Faint Yellow Slightly Green	Brown Slightly Violet	Light Red
Yellow	Orange	Yellow Orange	Orange Yellow	Yellow Green	Green	Reddish Blue
Light Green	Red-Gray	Yellow Grey	Green-Yellow	Intense Green	Blue Green	Light Purple
Deep Green	Red	Rusty Green	Yellow Green	Intense Green	Green Blue	
Light Blue	Violet	Orange Gray	Yellow Green	Green Blue	Vivid Blue	
Deep Blue		Gray slightly Orange	Greenish Slate	Blue Green	Intense Blue	Bright Blue-Violet
Indigo		Orange Maroon	Dull Orange Yellow	Dull Green	Dark Indigo	Deep Blue-Violet
Violet	Purple	Red Maroon	Yellow-Maroon	Blue or Green-Brown	Deep Blue Violet.	Deep Violet

(*Continued on page 200.*)

Meters

Induction Type Wattmeters

BURLEIGH CURRIER

General Application of Theory.—Alternating-current induction type integrating wattmeters depend upon the same basic principles for their operation, and in general differ only in the manner in which the principles are applied and in the details of construction.

Series and shunt windings are provided which are arranged in such relation that they produce a rotating magnetic field by the split-phase method, which cuts a close-circuit secondary and causes it to rotate.

The closed secondary consists of a disc or cup-shaped rotor, made of aluminum, which is mounted to rotate through the magnetic fields and also between the poles of permanent magnets which produce a retarding effect and serve as a regulating device.

The series winding consists of two practically non-inductive current coils, each having a few turns of comparatively large wire. These coils are wound in opposite directions and connected in series with the circuit.

The current coils are generally mounted on laminated-iron cores or poles which project directly toward the rotor, thus directing and concentrating the magnetic flux.

(*Continued from July Issue*)

The shunt windings consist of shunt and impedance coils, which are wound with a great number of turns of fine wire and mounted on laminated-iron cores to produce a large phase displacement of the field.

Some shunt coils are designed with sufficient impedance to be connected directly across the main circuit; others are designed to be connected in series with a separate impedance coil. In the latter case the shunt coil is mounted on a separate laminated-iron core which provides poles for concentrating the magnetic field that acts directly on the rotor.

Phase compensation for securing an exact 90-degree phase displacement of the shunt field is accomplished by an arrangement of auxiliary windings or coils and by closed-circuited secondaries used in combination with the main coils of the potential circuit.

Compensation for static friction is accomplished by the use of closed-circuited loops or secondaries and by auxiliary coils that are arranged in such relation with respect to the field of the potential coils that they produce an unbalanced or unsymmetrical condition of the potential field, thus establishing a slight rotating-field effect. Provision is made for regulating the magnitude of this effect, generally by varying the position of the secondaries.

The several makes of induction type wattmeter are identical in many respects. The illustrations will show the general arrangement of the principal parts and the connections of the various coils. A description will be given of the essential parts and their functions, also the methods of obtaining the proper phase relation of the magnetic fields and the principle of the arrangement used to compensate for friction.

In the vector diagrams the various fields are plotted separately, in order to show the manner in which the resultant field and its phase relation are determined. The length of the lines represents the magnitude of the components and the relative positions represent the relative phase relations. For the purpose of demonstration. the phase displacement and magnitude of the components are generally exaggerated.

WESTINGHOUSE TYPE B INTEGRATING WATTMETERS.

Description.—The arrangement of the parts, coils and connections of the

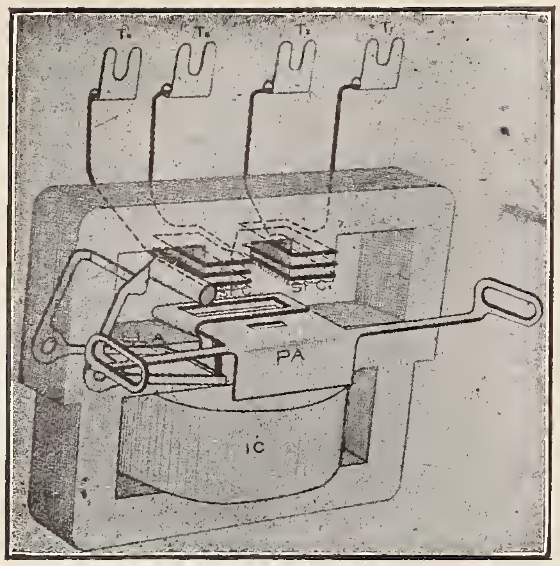


Fig. 13—WESTINGHOUSE TYPE B INDUCTION WATTMETER

Type B induction meter is shown diagrammatically in Fig. 13, which is a front view of the interior; the disc, shaft and permanent magnets being omitted for simplicity. The parts are lettered in the figure, for reference, and the function of the various parts and coils are described as follows:

SFC and *SFC*$_1$ are the main series field coils, which are wound in opposite directions. These coils produce the series field proportional to the current in the circuit.

IC is the impedance or shunt coil, which produces the shunt field proportional to the impressed e.m.f.

PA is the phasing adjustment or closed secondary, for producing the proper phase relation of the shunt field, for both high and low-frequency circuits. The adjustable strip is entirely out of the field for 125 cycles and is pushed in for 60 cycles. Adjustments are made according to marks on the strip.

LLA, the light-load adjustment, is a closed secondary consisting of one turn of copper arranged to produce the necessary starting torque to compensate for friction and also serves as an adjustment for light loads. Proper adjustment is obtained by swinging one side or edge of the coil or device either up or down in the air gap of the magnetic circuit.

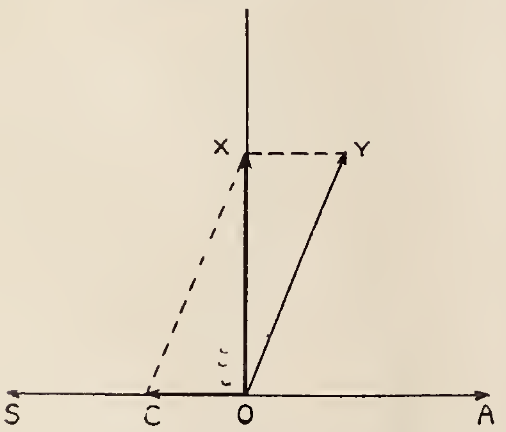


Fig. 14—VECTOR DIAGRAM FOR WESTINGHOUSE INDUCTION WATTMETER

T_1, T_2, T_3, T_4 are the meter terminals connected to the series windings, as shown.

Method of Obtaining 90-Degree Phase Relation.—Compensation for the small decrease in the angle between the shunt fields and voltage, caused by the copper and iron losses in the shunt circuit, is obtained by placing a short-circuited copper secondary directly in front of the projecting pole of the shunt electromagnet.

The magnetic field of the shunt coil induces current in the stationary closed secondary and consequently establishes a magnetic field, which, acting with the shunt field, produces a resultant field lagging approximately 90 degrees. An additional adjustable closed secondary is interposed over the shunt magnet pole, and is arranged so that its position may be varied, consequently the induced current and resulting field of the closed-coil arrangement is also varied. By varying the position of the movable secondary, the compensation necessary to obtain an exact 90-degree relation on

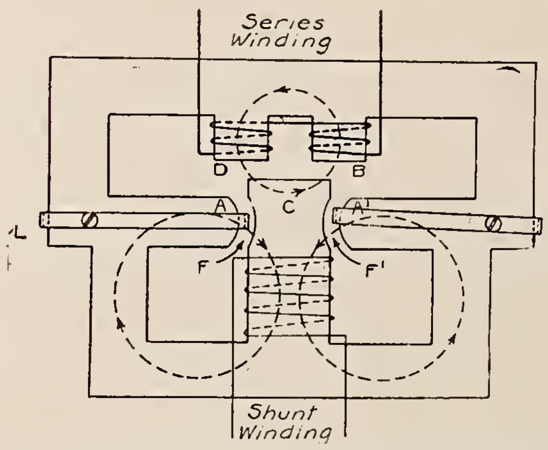


Fig. 15—LIGHT-LOAD ADJUSTMENT ON WESTINGHOUSE TYPE B INDUCTION WATTMETER

different frequency circuits may be obtained. This method may be better understood by referring to the vector diagram, Fig. 14.

OA represents the e.m.f. impressed on the shunt winding.

OY represents the current through the shunt winding, lagging with respect to the impressed e.m.f. due to the reactance of the shunt coil.

YOA represents the angle less than 90 degrees, due to iron and copper losses in the shunt circuit.

OS represents the voltage induced in the closed secondary which is approximately opposite in phase relation to the voltage of the shunt circuit.

OC represents the current in the closed secondary, which is in phase with the voltage *OS* (the magnitude of *OS* and *OC* being exaggerated).

OX represents the magnitude and direction of the resultant field produced by the combined effect of the currents *OY* and *OC*.

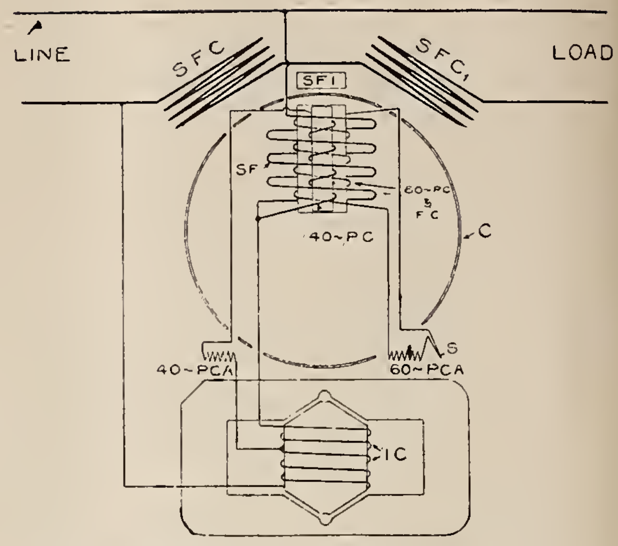


Fig. 16—FORT WAYNE TYPE K INTEGRATING INDUCTION WATTMETER

By changing the position of the closed secondary, the magnitude of *OC* can be increased or decreased, thereby shifting the position of the resultant *OX,* to obtain the proper 90-degree phase relation with respect to *OA,* thus compensating the meter to register correctly under varying conditions of power factor.

Friction Compensation and Light-Load Adjustment.—Friction compensation is obtained by two short-circuited copper loops, *L* and *L'*, which are located in the air gaps, *F and F'*, of the shunt circuit, as shown in Fig. 15. One of the loops with adjustable arm is shown in detail in Fig. 13, *i. e., LLA.*

When the potential circuit only is energized, the action obtained by the use of the loops is as described.

1. Assuming that the loops are not present, it can be seen that when the air gaps are fixed and equal in dimensions there will be a balanced shunt magnetic circuit.

2. When a loop is introduced in one air gap the reaction of its induced currents on the flux of the electromagnet will produce a slight unbalancing of the shunt magnetic field, tending to cause rotating of the disc.

3. Placing a similar loop in the opposite air gap will by its counter-unbalancing effect tend to neutralize the effect of the first loop, and by bringing both loops to the same relative positions in the gaps the original balance will again be established.

4. The loops are so adjusted that the resultant unbalancing produces a sufficient torque to overcome the friction of the moving element. Friction compensation is thus effected by the use of loops, one of which is sometimes replaced with a closed coil wound around the magnet pole, and the adjustment is made, as described, with the remaining loop.

FORT WAYNE TYPE K INTEGRATING WATTMETER

Description.—The arrangement of the parts and connections of the vari-

ous coils of the Type K induction meter are shown diagramatically in Fig. 16. The function of the various parts and windings will be described, and the parts are lettered for reference.

C is a closed-circuited aluminum cup or armature, arranged so as to be cut by the fields of the series and shunt coils.

SFC and *SFC*¹ are the main series field coils wound in opposite directions.

SF is the shunt field coil to produce a field that is proportional to the impressed e.m.f.

SFI is a portion of the shunt field iron used to complete the magnetic circuit for the shunt field coil.

60-cycle *PC* is a closed-circuited secondary winding or phasing coil for lagging the meter for circuits of standard frequency.

60-cycle *PCA* is an adjustable resistance provided to regulate the current in the 60-cycle phasing coil.

140-cycle *PC* and *FC* is the coil arranged to produce a starting torque for friction compensation, which is also used as a phasing coil to lag the meter for high-frequency circuits.

LLA, shown in Fig. 20, is the light-load adjusting arm.

140-cycle *PCA* is an adjustable resistance placed in series with the friction compensating coil, both being connected in series and across a few turns of the impedance coil *IC*.

IC is the reactance or impedance coil, and is connected in series with the shunt field coil.

S is a switch in series with the 60-cycle phasing coil and the adjustable resistance, and provides a means for adapting the meter for a high or low-frequency circuit. When the switch is open the meter is properly compensated or lagged for a 140-cycle current, and when closed the meter is compensated for a 60-cycle circuit.

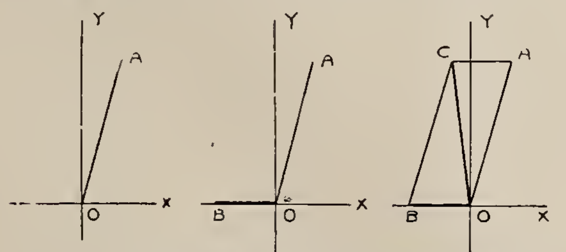


Fig. 17—FUNDAMENTAL VECTORS OF SHUNT CIRCUIT OF TYPE K METER

Phase Relations of Magnetic Fields.—The phase relations of the magnetic fields produced by the various coils in the Type K meters are represented diagrammatically in Figs. 17, 18 and 19.

In the vector diagrams, the line *OX* represents the position of the e.m.f. impressed on the shunt circuit, and the line *OY* represents the proper phase position for the field of the shunt circuit, which is 90 degrees from *OX*.

As the Type K meter is designed to operate on either a 140 or a 60-cycle circuit, it is necessary that it should be double lagged; that is, the phase relation of the fields should be properly compensated for each frequency. The lagging of the meter for a 140-cycle circuit will be considered first.

OA (diagram *a*) represents the phase position and magnitude of the field established by the shunt field coil; the large displacement of the field with respect to *OX* resulting from the large reactance component, is obtained by the impedance coil and shunt field coil.

OB (diagram *b*) represents the phase position and magnitude of the field due to the currents induced in the closed-circuited armature by the fields of the shunt coil.

OC (diagram *c*) represents the direction and magnitude of an equivalent or resultant field produced by the fields *OA* and *OB*. The phase position of *OC* is beyond 90 degrees.

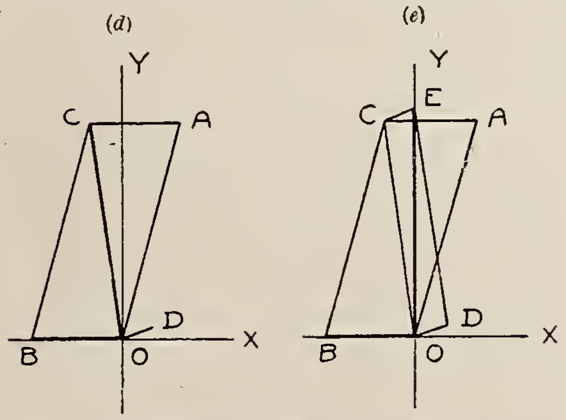


Fig. 18—VECTORS FOR 40-CYCLE COMPENSATION OF TYPE K METER

OD (diagram *d*) represents the component field produced by the 140-cycle phasing coil or friction compensator, the magnitude of this component being controlled by a resistance in series. The resistance may be varied to increase or decrease the amount of current in the phasing coil, thus controlling the magnitude of the field produced.

OE (diagram *e*) represents the resultant field produced by the combined action of the components *OC* and *OD*. The magnitude of the component *OD* is adjusted so that *OE* will assume a 90-degree position. Therefore the meter will accurately register the true energy of the circuit.

When a meter lagged, as described, for a 140-cycle circuit is connected to a 60-cycle circuit, the 90-degree relation of the magnetic fields no longer exists, and the resultant flux represented by *OE* has a phase position less than 90 degrees, as shown in diagram *f*. This is due to the reduction in the rate of alternations of the circuit and consequent decrease in the reactance, which lessens the magnitude of the components *OB* and *OD* and the angles *XOA* and *XOD*, and therefore alters the phase relations.

In order to again establish the 90-degree phase relation, the 60-cycle phasing coil switch *S* is closed, which introduces another component field.

OF (diagram *g*) represents the phase position and magnitude of the field produced by the 60-cycle phasing coil.

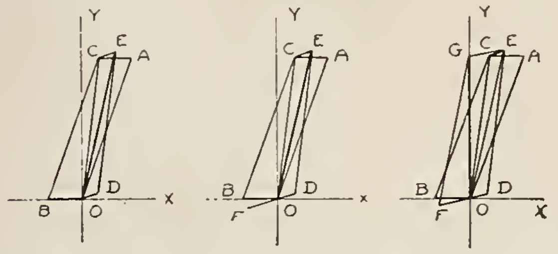


Fig. 19—VECTORS FOR 60-CYCLE COMPENSATION OF TYPE K METER

OG (diagram *h*) represents the resultant field produced by the combination of the component *OF* and resultant component *OE*. This field, *OG*, lies on the line *OY* and has a phase displacement of 90 degrees with respect to *OX*.

The meter is then properly lagged for a 60-cycle current and will accurately register the energy in the circuit.

Light-Load Adjustment or Friction Compensator.—One of the phasing coils is wound on an adjustable arm and placed centrally in the shunt field coil, producing the desired additional field to give a resultant shunt field having a 90-degree relation with respect to the impressed e.m.f., as explained. The field established by this coil is not in phase with that of the shunt coil, and when in position in the shunt coil has a demagnetizing effect on account of the direction of its winding and consequent phase position of its field. When moved from the central position the field established cuts the rotor at a slight angle and produces an unsymmetrical condition and slight rotating-field effect. A torque is thus produced that is sufficient to compensate for the friction without disturbing the phase displacement of the shunt field as a whole.

Fig. 20 shows the component parts of a Type K2 meter; the arrangement of the parts and manner in which they are assembled and connected is also shown.

Fig. 21 shows diagrammatically the connections and coils arranged in their relative positions.

Fig. 22 shows diagrammatically the connections of the potential circuit and its auxiliary coils.

GENERAL ELECTRIC TYPE I INTEGRATING WATTMETER

Description.—The arrangement of the parts and connections of the coils of the Type I induction meter are shown diagrammatically in Fig. 23, which is a rear view. The figure is lettered for reference.

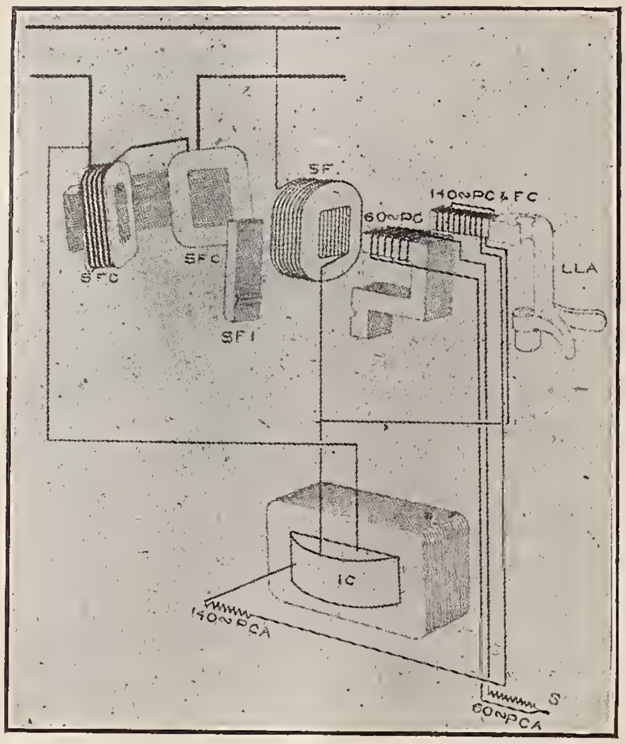


Fig. 20.—RELATION OF PARTS IN TYPE K2 METER

The function of the various coils and parts will be described.

D is an aluminum disc, mounted to rotate between the series and shunt, magnet poles, also between the poles of the permanent magnet brake.

SFC and *SFC*[1] are the main series field coils wound in opposite directions on projecting iron cores. These coils produce the series field proportional to the current in the circuit.

IC is the impedance coil producing the shunt field proportional to the line e.m.f. This winding has a high reactance and is connected directly across the main circuit. The magnetic field produced lags nearly 90 degrees with respect to the e.m.f. impressed.

PC is a phasing coil consisting of a closed secondary or lagging winding, which produces a sufficient additional field to establish the exact 90-degree phase relation required.

AR is an adjustable resistance in series with the closed secondary winding to regulate the magnitude of the current.

LLA is the light-load adjustment, a closed secondary of one turn of copper placed around the shunt field magnet pole and arranged to produce the necessary unbalancing of the shunt field to compensate for friction.

L is a lever provided for adjusting the position of the closed secondary *LLA* with respect to the iron core.

T^1, T^2, T^3 *and* T^4 are the main terminals for connecting the meter in circuit.

BB is the bus bar.

Phase Relations.—The phase relations of the magnetic fields produced by the various windings in the Type I meter are represented diagrammatically in the vector diagrams, Fig. 24. In the diagram the phase relation and magnitude of the components are magnified in order to make the description clear.

OA represents the impressed e.m.f. applied to the impedance coil or shunt winding.

OB represents the current in the impedance coil, which lags nearly 90 degrees behind the impressed e.m.f., due to the reactance.

OE represents the e.m.f. induced in the closed secondary winding *PC*, Fig. 23, and is almost 180 degrees from *OA*.

OC represents the current in the closed secondary *PC*. This current is in phase with the induced e.m.f., *OE*, as the winding is practically non-inductive.

OD represents the magnitude and direction of the resultant magnetic field produced by the combined magnetizing effect of the shunt current *OB* and the closed secondary current *OC*. By means of the resistance *AR*, Fig. 23, the magnitude of the current *OC* may be either increased or decreased, thereby shifting the position of the resultant magnetic field *OD* until a phase relation of exactly 90 degrees is obtained between *OA* and *OD*.

The e.m.f. and current induced in the closed-circuited armature or disc and light-load adjusting coil are not shown in the diagram, as they are at all times practically in phase with the e.m.f. and current *OE* and *OC*.

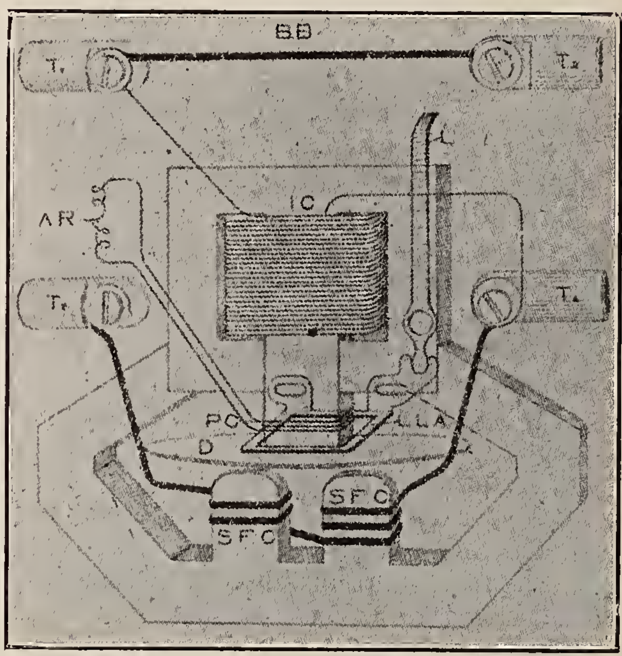


Fig. 23—GENERAL ELECTRIC TYPE I INDUCTION WATTMETER

When the resultant shunt field *OD* lies 90 degrees from *OA*, the meter will accurately register the energy on inductive and non-inductive loads.

Friction Compensation on Light-Load Adjustment.—Friction compensation is obtained by placing around the shunt field core a movable copper turn or closed secondary *LLA*, Fig. 23. The turn is made to fit closely over the lower end of the core of the shunt field magnet and has internal dimensions large enough to permit moving it horizontally either to the right or left.

The effect of the closed secondary turn is practically the same as the effect produced by the shading ring or coil on the pole of a single-phase induction motor.

Assuming that the secondary turn is not present, it is evident that with current in the potential circuit and no current in the series circuit, the shunt

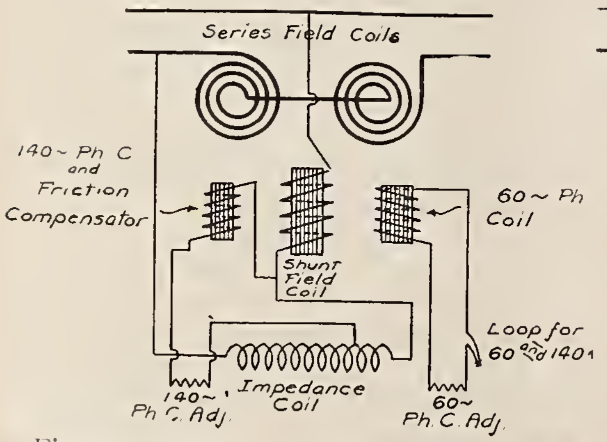


Fig. 21.—INTERNAL CONNECTIONS OF TYPE K METER

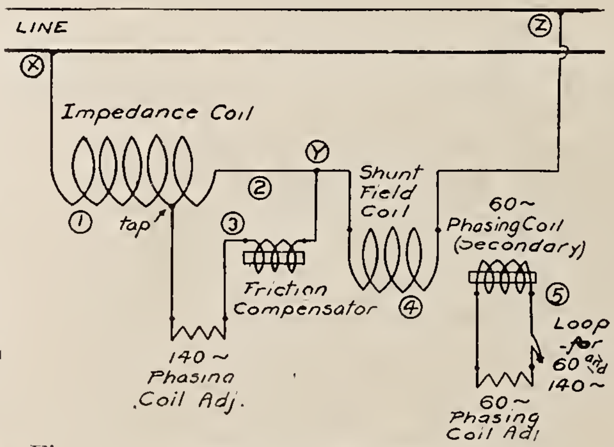


Fig. 22.—CONNECTIONS OF POTENTIAL CIRCUIT IN TYPE K METERS

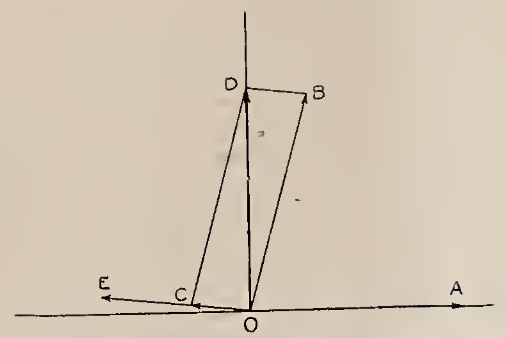


Fig. 24—VECTORS FOR TYPE I INDUCTION WATTMETER

field would be magnetically balanced. Introducing the secondary turn centrally with respect to the magnetic field would not alter the balanced condition.

Moving the turn in either direction would produce a slight unsymmetrical condition of the field, which would result in a torque. This unbalanced condition is due to the reactive effects of the field of the secondary, which would then be greater on one side of the shunt field pole. This produces the effect of a slight rotating field. The turn may be adjusted to such a position that the unbalanced field will produce sufficient torque to

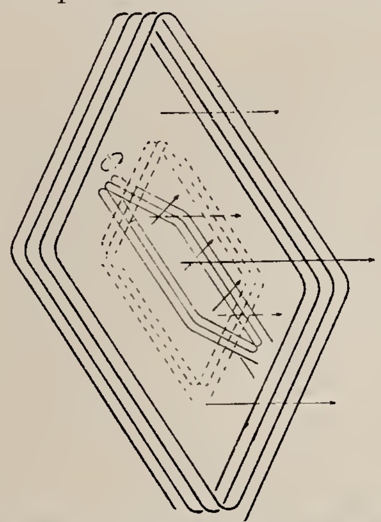


Fig. 25—TURNING ATTRACTION BETWEEN TWO COILS

overcome the friction of the moving element.

THEORY OF COMMUTATED TYPE MOTOR METERS

General Principles.—The electromagnetic action between two coils and the method in which this principle is utilized and applied in the construction of commutated type of motor meters is illustrated in the following description:

When two coils, as shown in Fig. 25, are supplied with current, a magnetic field will be established by each coil, and the direction of the fields will depend on the direction of the current in the coils. Magnetic poles will be established which will produce an attraction or repulsion, depending on the relative polarity and position of the coils. When one coil is movable and the other is stationary, the movable coil will assume such a position that its magnetic field will be in the same direction and will coincide with the field produced by the stationary coils. The principle of the magnetic action described is applied in commutated motor meters in the following manner.

The current coils produce a magnetic field having a definite direction, and, as the coils are in series with the main circuit, the strength of the field will be proportional to the main current. They are arranged sufficiently

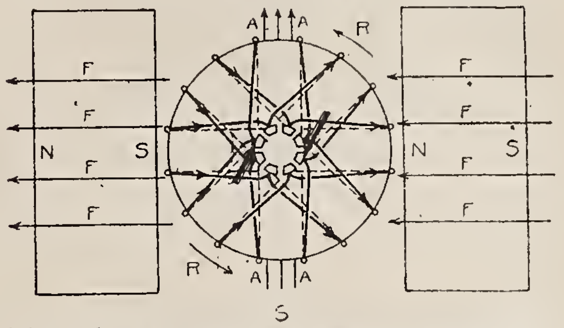


Fig. 26.—MAGNETIC FIELDS ESTABLISHED IN A FUNDAMENTAL COMMUTATED MOTOR METER

close together to produce the effect of a single coil, and practically surround the armature.

The armature is of the closed-coil type, with taps from the winding to the commutator segments, and as the current enters through but two taps which are connected to diametrically opposite points, the armature circuit is virtually divided into two parts which are in parallel. When the current enters through the brushes and commutator it will therefore pass in a downward direction in one-half of the armature and upward in the other half.

The magnetic field established by the armature coils will be an equivalent or resultant field having a general direction, which will depend on the position of the armature coils with respect to the commutator segments and to the position of the brushes on the commutator. The strength of the armature field will depend on the current in the armature circuit and will be directly proportional to the e.m.f. of the main circuit.

In Fig. 26 is shown the direction of the magnetic field established by the current coils, as indicated by the arrows marked *F*. The polarity of the coils is indicated by the letters *N* and *S*.

By virtue of the relation between the armature coils, commutator segments and brushes, the general direction of the armature field is practically at right angles to the field of the current coils, as shown by the arrows marked *A* and the poles *N′* and *S′*. For demonstration, only the direction of the equivalent armature field is indicated.

The magnetic action between the two fields produces a torque that causes the armature to turn and endeavor to assume such a position that its field will coincide with the field produced by the current coils. When the magnetic poles are as shown in the diagram, the direction of rotation will be as indicated by the arrows *R*, the magnetic pole *S* of one field coil attracting the armature pole *N′* and repelling the pole *S′*, while the pole *N* of the other field coil attracts the armature pole *S′* and repels the pole *N′*.

An armature having but one coil and without a commutator would turn only until the direction of its magnetic field was the same as the field produced by the current coils and then it would stop. However, an armature as constructed in practice has a sufficient number of coils connected to an equal number of commutator segments, so that when the armature is turned a small amount another set of commutator segments will come under the brushes and again establish a field approximately at right angles to the field of the series coils. When this condition is again established a turning effort or torque is again produced, causing the armature to turn until another set of commutator segments come under the brushes, and so on. The magnetic field of the armature will therefore always be established in practically the same general direction with relation to the field of the current coils, thus causing a continuous rotation.

The torque exerted on the armature is proportional to the product of the strength of both the current and voltage fields and is therefore proportional to the product of the current and the voltage, or to the actual power in watts.

General Description.—Meters of the commutated type, in general, consist of three essential parts, the motor, the brake or retarding device, and the registering mechanism.

The motor, as generally construct-

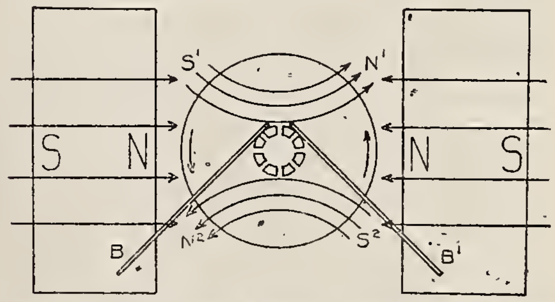


Fig. 27.—DUNCAN ASTATIC MULTIPOLAR MOTOR METER WITH FOUR-POLE ARMATURE AND OPPOSING FIELDS

ed, requires the following principal parts, which are necessary for the arrangement of the electrical circuits: The main current coils, armature, resistances, compensating coil, shaft, commutator and brushes. The electrical circuits, essential for the operation of the motor, are the current or series circuit and the pressure or

potential circuit, both of which are constructed without iron, except in special types.

The current circuit usually consists of two stationary coils, having a few turns of comparatively large wire wound in a circular or rectangular form. These coils are mounted parallel in close relation so that they practically surround the armature, which is mounted to rotate centrally within them. The current coils are connected in series with the main circuit, and the total current passes through them in a direction that will produce magnetic fields that coincide.

A single current coil is sometimes used, having the armature placed centrally within the field.

The potential circuit consists of an armature, a resistance and a compensating coil, all of which are in series and connected directly across the main circuit.

The armature is generally of the closed-coil type, having a lap winding consisting of several coils, usually eight, as shown in Fig. 26. These coils are made of fine wires and are wound upon a light non-magnetic frame, which insures rigidity and serves as a means of mounting to permit rotation. Loops are made in the winding, serving as taps to the coils, and are connected to a small commutator, with which the armature is mounted on the shaft.

An armature of the open-coil type is sometimes used, consisting of three coils symmetrically arranged around the shaft—connected to a three-part commutator. The principle involved in producing rotation is practically the same as in a closed-coil armature.

Armatures are made in either ball or cylindrical shapes, so as to conform to the shape of the current coils and to properly occupy the space within the enclosure of the coils, so as to be cut by as much of the magnetic flux as possible.

The armature, commutator and disc for the magnetic brake are mounted on the same shaft, which rotates vertically, being supported at the bottom by a cushioned jewel bearing and at the top by a small guide-pin bearing.

The brushes serve as conductors for the current to enter the armature through the commutator. For two-pole, lap-wound armatures the brushes span one-half of the commutator segments, for four-pole, wave-wound armatures one-quarter, and for three-coil armatures the span must be nearly two-thirds.

Commutators are usually constructed of small silver segments of a number equal to the number of coils in the armature and have a small diameter to reduce the rubbing friction of the brushes.

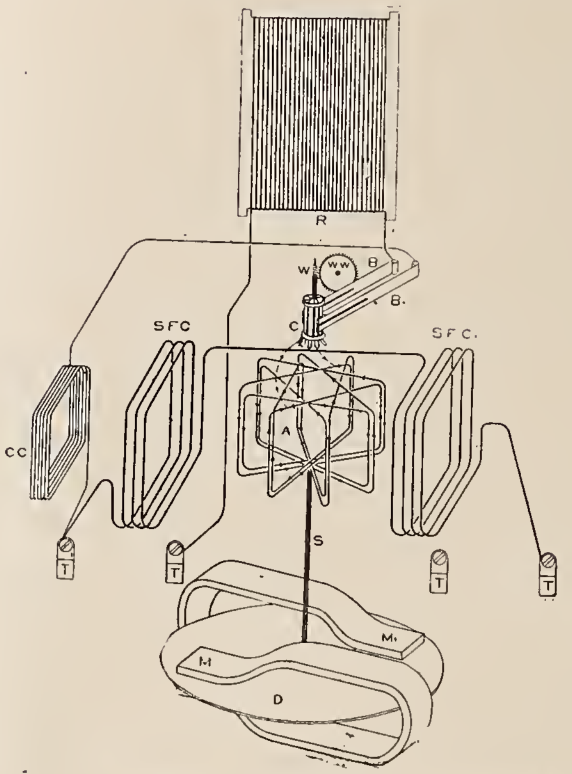


Fig. 28.—GENERAL ELECTRIC THOMPSON RECORDING WATTMETER

The resistance is used to reduce and limit the current in the potential circuit so that small wire can be used in the armature winding. This permits the use of a light and compact armature with the necessary ampere-turns to produce the desired strength of field. The resistance also reduces the voltage drop across the armature and indirectly diminishes the deteriorating effect of sparking at the brushes, should any occur. The resistance must have no inductive effect on the armature or field circuits, and it is generally constructed of fine wire wound upon cards, spools or tubes, which are mounted either within the meter, on the back of the meter base, or in a suitable box supplied as a separate unit. Another method of construction is to wind the resistance and friction compensator into a single coil, the principle of which will be subsequently described.

A certain amount of frictional resistance exists in every meter, consisting principally of the friction of the bearings, registering mechanism and of the brushes on the commutator. This friction makes it difficult to obtain a speed of the disc on light load that is proportional to the energy consumed. In order to produce the least departure from the straight-line law, it is necessary to compensate for the existing and subsequent friction.

An auxiliary winding or friction compensating coil, consisting of a number of turns of fine wire, is connected in series with the potential circuit and is placed in the same relation with respect to the armature as the main current coils. The auxiliary winding establishes a magnetic field, having a constant strength, which depends on the number of turns in the coil and on the current in the potential circuit. The polarity of the auxiliary coil is essentially the same as that of the current coils and produces just sufficient torque to overcome the friction.

As the friction does not always remain constant, several methods are employed to vary the strength of the field produced by the compensating coil.

The effect of the field of the auxiliary winding is regulated by mounting the coil on an adjustable bracket, so that its distance and position with respect to the armature may be altered; or it is varied by making the coil stationary and regulating the strength of the current by shunting it, or by changing the number of effective turns in the winding.

The adjustable coil is constructed to pass within the windings of the current coil, so as to permit adjusting to a position very near the armature. A type adjustable coil is made which has sufficient resistance to be connected directly across the circuit. This coil is virtually constructed in two sections, which are wound in opposite directions, each section having a different number of turns. The fields

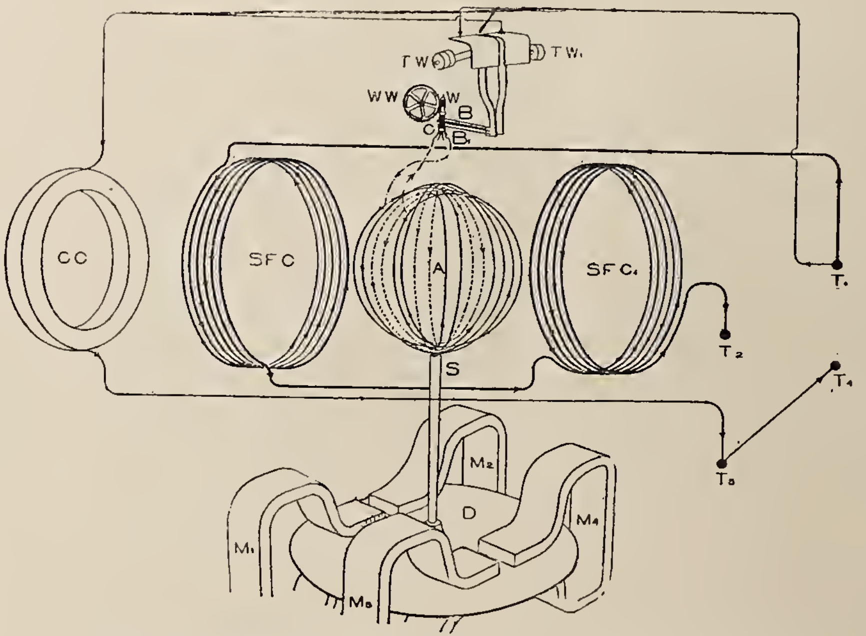


Fig. 29.—GENERAL ELECTRIC TYPE C COMMUTATED METER

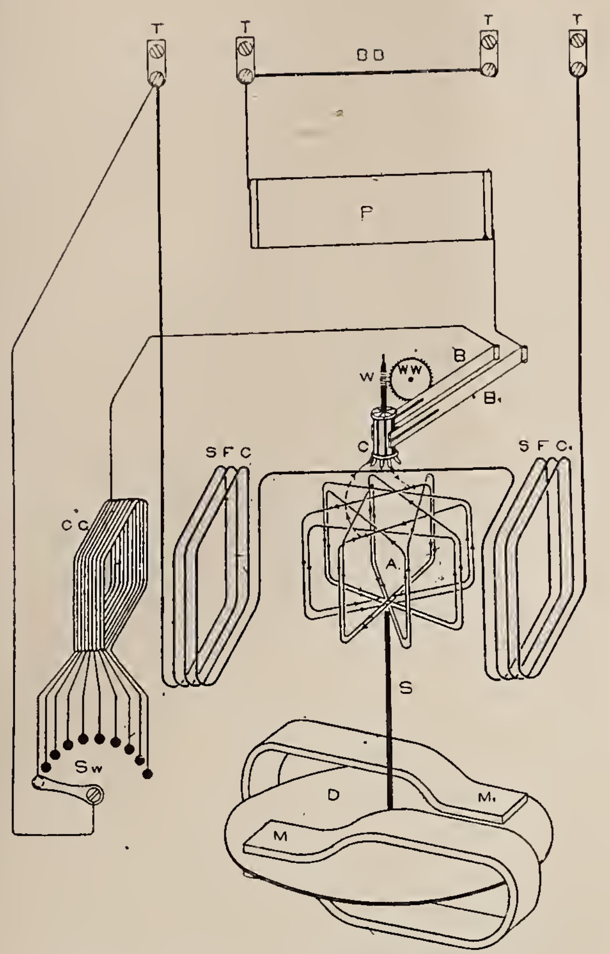


Fig. 30.—DUNCAN TYPE E COMMUTATED INTEGRATING MOTOR METER

produced tend to neutralize, but as one section has a greater number of turns its field will predominate, therefore the effective field will depend directly on the difference between the number of turns in the two sections.

The field produced by the stationary type coils is sometimes varied by shunting the coil with a resistance. An adjustable contact is provided, which may be connected to various taps to alter the value of the resistance. Stationary coils used for friction compensation are provided with taps connected to different turns of the coil. The taps are connected to contacts on a suitable multipoint switch, which is adjusted to vary the number of effective turns, in order to produce the desired strength of field.

Multipolar Type.—The principle employed in the design of an astatic multipolar type meter is shown diagrammatically in Fig. 27. The current coils are so wound and connected that each coil establishes a separate field having opposite polarities, as shown, the coils being arranged sufficiently far apart so that the fields do not neutralize each other.

A four-pole closed-coil drum armature with a wave winding is provided, which establishes fields having polarities as shown.

Rotation of the armature is produced by the attraction and repulsion of the field, as indicated; the north poles of the current coils repel the poles N' and N^2, and attract the poles S' and S^2, established by the armature coils.

Commutated meters, in general, have practically the same essential parts, therefore in Figs. 28, 29, 30, 31 and 32 the same abbreviation will, in each case, represent the same part of the meter, as follows:

- A = The armature
- AR = Adjustable resistance to vary the field of CC
- BB = The bus bars
- B and B' = The brushes
- C = The commutator
- CC = The friction compensating coil
- D = The disc
- FLA = Full-load adjustment
- LL *or* CA = Light-load or creep adjustment
- M, M' M^2, etc. = The drag magnets
- MS = Magnetic shield
- P = Pinion
- R = The resistance
- S = The shaft on which is mounted the armature, commutator and disc
- SFC and SFC' = The current or series field coils
- SW = The switch for compensating coil

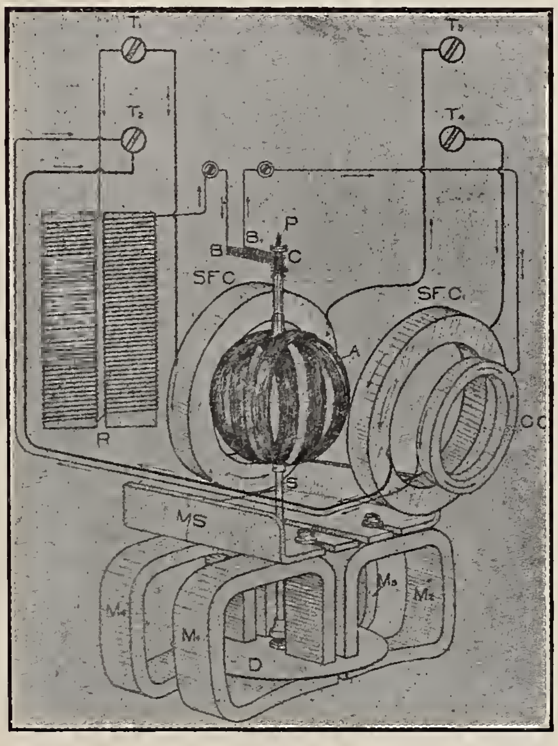


Fig. 31.—WESTINGHOUSE TYPE DIRECT-CURRENT COMMUTATED MOTOR METER

- T, T^1, T^2, etc. = The connecting terminals
- TW-TW' = The tension weights for brushes
- W = The worm on the shaft
- WW = The worm wheel of the registering mechanism

PRINCIPLE OF THE MERCURY MOTOR METER

All mercury motor meters are based upon the discovery that when a current of electricity is passed radially across a copper or aluminum disc immersed in mercury, and the path along which the current flows is subjected to the field of a strong magnet, rotation of the disc is produced. The reaction between the field of the current in the disc and the field of the magnet produces the rotation of the disc. This, of course, is the fundamental basis upon which any electric motor operates, and the manufacturers of mercury motor meters have simply utilized this principle with modifications and additions.

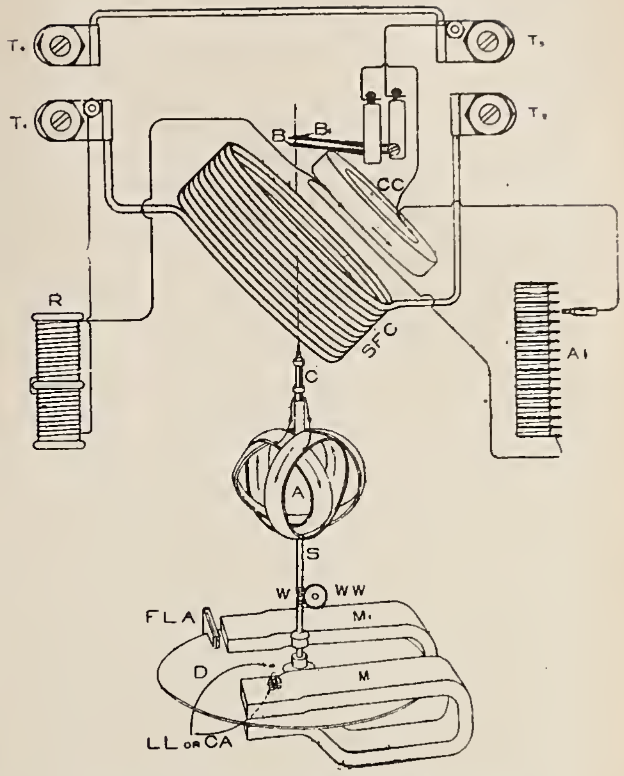


Fig. 32.—COLUMBIA TYPE ALTERNATING-CURRENT COMMUTATED MOTOR METER

In general, therefore, we may say that any mercury motor meter consists essentially of a rotable cylinder, disc, or motor element, partly or totally submerged in mercury so that current can be led in and out from the movable element by the mercury acting as a contact-maker, fixed metallic contacts of one form or another

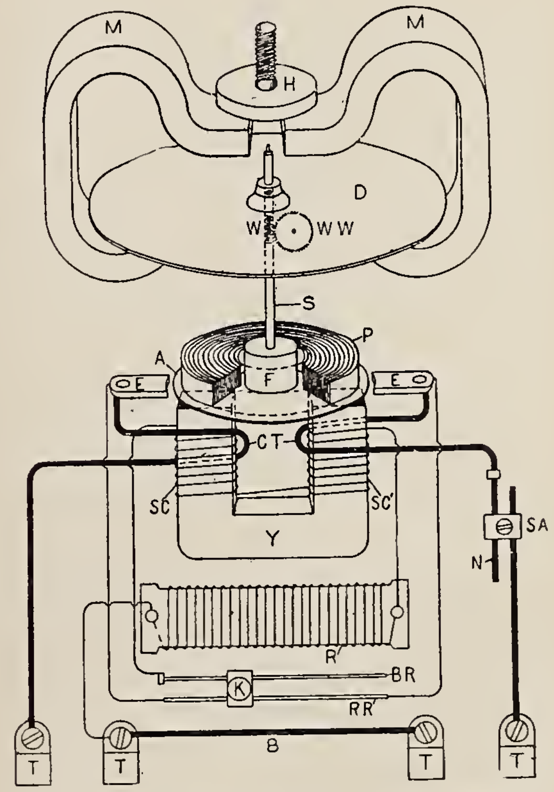


Fig. 33.—SANGAMO DIRECT-CURRENT MERCURY MOTOR METER

being set in the walls of the chamber containing the mercury and the disc. An electromagnet properly set with respect to the disc or armature will, when energized, cause rotation of this armature, and this rotation may be proportional to watt-hours. This principle is adaptable either for direct or alternating current, according to the construction employed.

The following refers to Figs. 33 and 34, and indicates the essential parts of the Sangamo direct-current and alternating-current meters:

1. Letters common to both Figs. 33 and 34.

A = Copper-disc armature immersed in mercury

B = Bridging wire across middle pair binding posts

BR = Brass-wire rod of low resistance, forming part of light-load adjustment

D = Damping disc—aluminum

EE = Copper contacts, leading current in and out from mercury chamber and armature

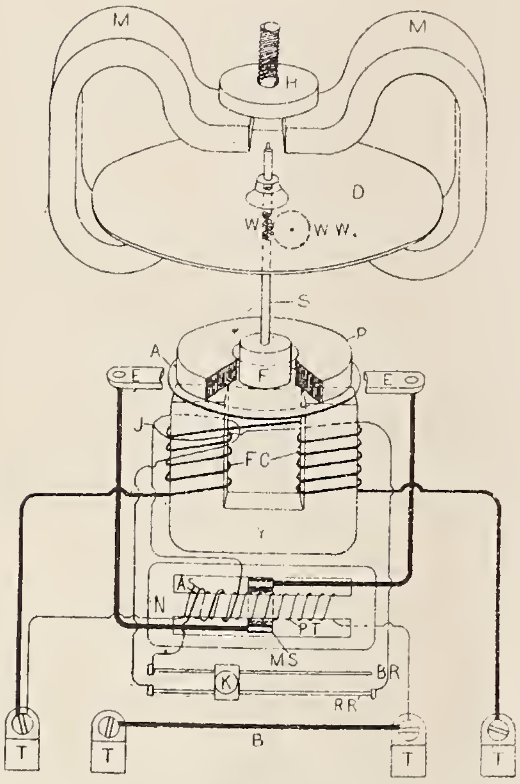


Fig. 34.—SANGAMO ALTERNATING-CURRET MERCURY MOTOR METER

F = Buoyancy float, riveted on armature, giving lift or slight buoyancy to entire moving system

H = Soft-iron disc for main or heavy-load speed adjustment is carried on vertical screw and operates by shunting flux between upper jaws of damping magnets *MM*

K = Clamp slider for light-load adjustment—slides on wires *BR* and *RR'* and clamps with thumb-screw

MM = Permanent magnets for damping

P = Laminated (spirally-wound strip) steel ring or plate for return path of magnetic lines above *A*

RR' = Resistance wire rod of very high resistance, forming part of light-load adjustment

S = Shaft of moving element

TT = Binding posts

W = Worm driving *WW*

WW = Worm wheel

Y = Laminated steel yoke for magnetic field

2. Letters in Fig. 33 only

CT = Series compounding turns which increase the field strength and therefore the torque and speed on heavy load

N = High-resistance wire rod, forming, with copper wire and *SA*, the adjustment

R = Resistance in series with shunt coils *SC* and SC^1, depending in amount on voltage for which meter is used

SA = Sliding adjustable clamp for regulating potential drop through meter for current shunt—used in all capacities over 10 amperes.

SC and SC^1 = Shunt coils of many thousand turns, energizing *Y* proportional to line voltage

3. Letters in Fig. 34 only.

AS = Auxiliary secondary on transformer, giving about 0.125 volt, for light-load compensation; one end is connected to brass rod *BR*, the other end goes to *J*

FC = Series or load coils on *Y*

J = Branch in one end from *AS*, from which two small cables pass around poles of *Y*, one to give *forward* starting effect, the other *backward* effect

MS = One-turn heavy main secondary on *N*, giving about 0.033 volt and sending 20 to 25 amperes normally through *A*

N = Small internal transformer for furnishing low-potential current for large volume through the armature *A*

PT = Primary of transformer, connected across supply line like shunt coil of an induction meter

(*To Be Continued*)

The Principles of Illumination

COMPARISON OF THREE METHODS OF ILLUMINATION—COVE, CEILING AND CLUSTER LIGHTING.

Continued from page 193

(Test by New York Edison Co.)

Cove 4 ft. 9 in. below ceiling, on side walls. Ceilings and walls light cream color; ceilings broken by skylights, and two walls, by windows.

System	Average Candle-feet	Average Candle-fee per watt
Cove.	4.08	.00042
Ceiling	5.44	.00131
Cluster	2.18	.00092

HARM TO THE EYE.

The *maximum brightness* which the eye can withstand without bad effect is about 0.75 hefner-candles per sq. cm.

Carbon filaments of incandescent lamps are about 100 times, and the Nernst glower over 500 times, this limit.

(Schanz & Stockhousen, Jour. f. Gasbel. Vol. 50, 1907.)

This shows the immense importance of properly concealing brilliant lights. Cases of blindness from excessive light are common, and it is safe to say that nearly all eye weakness is attributable to imperfect knowledge and application of the art of illumination.

The admission of light to the retina is controlled to a certain extent by the varying area of the pupil which automatically adjusts itself to the incident light. This automatic adjustment, however, involves muscular action, and moreover follows the changes of light slowly, so that the retina is injuriously exposed for short intervals. For this reason a room should have good *general illumination* in order to avoid injurious contrasts of illumination. Thus a room with no light but that reflected from a table lamp onto the table, presents injurious contrasts. This should not be construed to mean that *shadowless illumination* is desirable. Where no shadows exist the eye is strained in attempting to distinguish the outlines of objects.

The *direction of illumination* is almost as important as the intensity. The eye is habituated to and is best suited to light coming obliquely from above. The glare of the sky is harmless, but a less intrinsic brilliancy reflected from snow, sand or water below, may have very serious effects.

Engine Room Management

By C. R. BROSIUS

Columbus Railway and Light Company, Columbus, Ohio

While designers and professors are discussing whether 2 or 3 per cent. may or may not be saved by the use of a steam jacket, customers are buying engines so proportioned to their work and so little adapted to the requirements they are expected to meet, that many times 2 per cent. is wasted continually. At the same time, great efforts are being made to reduce the steam consumption per horse power under test conditions for a few hours.* Plants are allowed to run day after day by men who are entirely competent from a standpoint of safety or reliability but have not the commercial knowledge necessary to adapt to continuously changing conditions and keep it doing its best.

A great deal of money is wasted and not a little prejudice incurred against patented devices by ill-directed efforts of enterprising managers to improve the efficiency of their plants without an intelligent analysis of the same. A plant may be in excellent condition as far as its boilers are concerned and evaporate a large amount of water per pound of coal, and still use an excessive amount of fuel for work performed by reason of wasteful engines; therefore any change in the boiler room can have but a slight effect upon the efficiency of the plant. Because some other manager has made a creditable saving by a change in fuel and alteration in his boiler setting, the adoption of a new grate, or some of the many appliances which are offered to improve boilers, it is no uncommon thing for a manager to apply the same and condemn the method because it results in failure in his case.

THE COLUMBUS RAILWAY & LIGHT COMPANY

POWER STATION TIME CHECK May 10, 1909.

NAME.. Henry Johnson No. 37

			charge
Cleaning steam drums #6 boiler	2	1/2	36
Putting new ratchet wheel on #6 stoker	1	1/2	36 b
Helped pack #2 boiler feed pump	1	1/2	42 d
Oiling economizers	2		22
Getting ready to clean #9 boiler	2		36
Sweeping up boiler room		1/2	41
7 A.M. to 5 P.M. Total Hours	10		

THE COLUMBUS RAILWAY & LIGHT COMPANY

POWER STATION. TIME CHECK May 12, 1909

NAME.....................CHAS. SMITH.....................No..21......

			charge
Fitting up piston rings H.P. #3 engine	3		35
Work on crank end H.P. steam valve			
#3 engine	4		35
Packed water end #2 house pump	2		42 c
Keyed #5 centrifugal pump all over	1		35 a
7 A.M. to 5P.M. Total Hours.	10		

The above applies more in general to small plants, as in a majority of large plants the engineer is consulted on such matters and held responsible for performance.

The best way to get the most work out of a steam plant with the least expenditure, is to find, first in what particular the plant is lacking, and then bring that part up to the standard if the product is a standard one. Find separately the efficiency of your boilers and engines. If your boilers are inefficient it may be because your rate of combustion is too high or too low for the amount of heating surface, a faulty setting, a poor heater or none at all, a wasteful fireman, or any one or more of a dozen other causes. Your engine may be of an inefficient type, underloaded or overloaded, badly set or leaking. Find the trouble and then go systematically to remedy it.

One of the most important money making adjuncts of the power station is the testing force. The average engineer, when asked at what water rate his engines are operating, will stare blankly at you and return a guess, which will probably be within a pound or two of the actual conditions. Every engineer, no matter how small his station or how few the employes, should have organized among his men, a testing force, and have piping so arranged that he can determine what each unit is doing. It is not necessary to make these tests elaborate and scientific; tests on engines should be simple, showing water rate per kilowatt-hour, with indicator cards. There should be an effort made to get a test of any unit when first installed or under the most favorable conditions, and in making any test afterward, compare it with the original test, and if at any time, tests are made that are better than the original, use them in making comparisons. After you have gotten your water rate and find it is high, you can, by analyzing the indicator diagrams, tell where the trouble is likely to be. The testing force, whether it is in the small plant and managed by the engineer, or in the large plant where you have one man to manage this department, can make efficiency tests on boilers, keep thermometers tested, and steam, draft, and vacuum gauges corrected, all of which work will result in increased savings. A decrease in steam consumption of one quarter pound per horse power per hour on an engine using 14 lb. steam per horse-power hour is a saving of 2 per cent. and can be reckoned directly in dollars and cents. At 7 per cent. CO_2 in your flue gases, you are heating enough unnecessary excess air to keep a duplicate of your furnace plant going, and at 5 per cent. CO_2 the excess would almost keep two additional plants running: it is the business of this testing force to produce more than 7 per cent. CO_2 and to so regulate combustion as to heat the smallest excess of air possible with the conditions existing.

A great problem which confronts the man in charge of the power station is a good system of making and recording repairs. In the steam plant, where the loss of heat units from the coal pile to the switchboard is about 91 per cent., you can readily see that some method must be devised whereby needed repairs can be attended to immediately, engines shall be so adjusted, rods shall be properly packed, steam leaks shall be repaired, and, most important of all, furnaces shall be kept in proper condition and all heating surfaces shall be regularly cleaned, for it is only by keeping everlastingly at the small things that adds the elusive one-half or one per cent. to your thermal efficiency and keeps it there. Very few concerns would think of putting as much money into any kind of business as there is invested in the average power station without having a clerk or bookkeeper, or a number of them, as was found necessary to keep an intelligent record of all transactions to show the condition of the business. I hear some one say, "Oh, our auditing department does that." True!—they do, as far as the financial part is concerned, but that does not help the engineer from an operating standpoint. It should not be necessary for the clerical force at the power station to have anything to do with cost, if the auditing department co-operates with the engineer-in-charge in giving him cost whenever desired.

In a large majority of plants to-day, it is the common practice for the chief engineer to depend largely upon his and his subordinates memory for records of the repairs made upon station apparatus. In the spring, the chief calls in the head watch engineer. "John, what time last year did we have No. 2 engine down?" "Well,

*O. E. L. A., 1909.

BOILER No. 13 1907 Station No.1.

DATE Month	Day In	Day Out	Cause	CLEANED Tubes Rows	Tubes Cir.	Nipples S.D.	Nipples M.D.	Nipples Int.	Steam Drums	Branch Pipes	REPLACED 1	2	3	4	Nipples S.D.	Nipples M.D.	Nipples Int.	Tubes No.	Tubes Row	Tubes Cir.	Headers	Days In	Days Out	Furnace	Remarks
Jan.	3	2	To clean water Box																			30	1	-	Ashes out-cleaned water-box. Put new discs in water column valves.
Feb.	14	6	To Clean	12	14	14	14	14	Baker							3-4 re-rolled						34	8	Cleaned-put 31 links & 4 collars in stoker- 27th-put new pawls on stoker	Packed all valves on front of boiler. Cleaned lower section rear headers. Put new disc in west blow-off valve. Ashes out-cleaned water-box. 27th-Put on new side door lining.
Mch.	11 30	10 17	Bursted Tube Arch falling down														Fig. 2	6	1			24 6	1 13	Put in new arch-used 8 arch tile 6"x12" and 72 arch tile 4"x12". Used 240 fire brick to repeir furnace walls. Put new apron on stoker magazine Put 1 new roller & 1 link in stoker.	Replaced 22 flame sheet brick. Ashes out-cleaned water-box Put 3/4" nipple in bleeder line. Repaired covering on feed pipes.

Fig. 2.

ENGINE No. 3 1907. Station No.

DATE Month	Day	BEARINGS H.P. Crank	H.P. Cross	L.P. Crank	L.P. Cross	Main	CYLINDERS High Pressure	Low Pressure	REPAIRS Crossheads H	Crossheads L	Guides H	Guides L	Plugs A	Plugs B	Plugs C	Plugs D	CONDENSER	PUMPS Air	Circulating	REMARKS
Jan.	16						New rings-R Bored out & bushed cylinder-size 22 7/8" Put in new piston & rings Put in new rod packing.	Opened cylinder scraped shoulder off head end. Rings O.K. Put in new rod packing.			Spotted	Spotted	New out-let valve rod and packing Bushed lom hang-ers and made new pins for same.	New out-let valve rod and packing.	Plug cut Planed off and scraped both seats Scraped both valves. Lined up all struts & pressure plates Turned off both valve rods and made rings to fit New latch block & pusher plate.	Packed both valve rods.	Cleaned	Keyed all over Examined valves O.K. Repacked both rods, water end Filed crank & cross-head boxes.	Keyed Crank & crosshead Put in new piston valve Made new cross-head pin & box-es rebabbitted crank box & main bearings. Trued up engine shaft and faced off coupling Impeller worn very badly. Screwed 1/2" pieces on impeller blades.	Packed throttle. Cylinder wearing fast size 23.316". Looked at gears O.K. except intermediate which will need to be filled soon (L.P. side) Rebabbitted top half of gear box on eccentric shaft. Took out and Cleaned up governor. Found one tooth broken out & pieces out of two others in bevel gear in governor case. Put in one new tooth. Looked at H.P. side gears, found intermediate loose, tightened up bolts & riveted them-gear will need to be babbitted soon. Put new gasket on oil shield.
	21	K	K	K	K															
	29																			
Feb.	2	K	K																	
	4																			
	26	K	K	K	K															
Mar.	28	Re-babbitted																		

Fig. 3.

let me see, April, I think"—stops and thinks a minute—"No, by George, it wasn't, it was in February, for you know we had good weather and our load dropped off, and we got her out sooner last year than usual." "Well, John, let me see, we scraped all the valves, didn't we?" "No, chief, we only scraped the high pressure valves. It was on No. 4 that we scraped all the valves"—again ponders awhile—"Now I can't be exactly sure about that either, because you know we broke a valve on one of the engines just a short time before, and of course the new one was in good condition, and the other was not reached for some reason. But just wait a minute. I've got it out here." Well, he goes to here and he digs up a precious little red-backed book—a present from some power specialty salesman—one cover about played out, greasy thumb-marked notes on boilers in the front, notes on engines in the back, notes on pumps in the middle, and the engineer proceeds to make "sure." Well, lo and behold you!—when he has made "sure," he finds that the scrapers were operated on all those valves and the engine was neither out in April nor in February, but in March. Gentlemen when you are trying to add that evasive one-half of one per cent. to the nine you already have, do not depend upon the uncertain memory of the chief repair man. No station, however small, should depend upon memory for those important matters.

The average power station has been most reluctant to adopt discipline similar to that in force in shops and manufacturing plants. The principal reason for this is, that the character of each man's work differs so much from the other's, that it has looked difficult to institute a system that would be effective in checking the work done. The most difficult part of this, however, is keeping check on repairs and stock for repairs. The writer has found the following methods to be of great assistance in this matter:

Any one in the station is permitted and requested to make a written report of trouble or defects of any character, and special blank forms are provided for the same. These reports are filed in the engine room, where the men assigned to repair such defects can see them; the man making such repairs O. K.s the report and it is turned in to the clerk, who enters it in his records in the proper place. In case the repair does not last for the time it should, or is not properly done, the man who did the work must give cause for it, and he has no way to escape because his signature is on the report. The chief engineer may never see these reports unless it is an important matter, or has not been attended to in a certain number of days. In this case, if the repair is not made in three days, the report, not O. K.d of course, goes to the chief engineer who adjusts the matter.

This method, while requiring lengthy explanation, relieves the chief of considerable work, and especially if he has charge of several plants widely separated, and it also insures the clerk getting a note of repairs for his records. In a large plant where efficient operation and a minimum cost depend upon the good condition of all machinery, it is extremely necessary, that some simple system be devised whereby repairs can be made when necessary, and not forgotten. This

system has proved its worth in this respect.

In cases of repair work which requires several days or weeks for completion, the great difficulty lies in getting information when the work is done. The best way to make sure of receiving notes of all repairs is to have each man state on his daily time check just what he has worked on during the day. See Fig. 1. Then, in case the report of repairs does not come in from the proper source, the clerk immediately secures the reports lacking. In regard to the boiler record—the information comes from two different sources and one checks the other. When a boiler is to be cut out, the head fireman is instructed by the boiler repair man to cut it out. The fireman makes a note of this on his daily boiler room report card, giving the time of cutting the boiler out and the reason for same. When the boiler is again cut into line, the fireman notes the time upon the card for that day. When the clerk receives the report of the boiler again being in service, he knows that there should be a report from the boiler repair man concerning the repairs made, and in case he has not received that report, he immediately gets it. The same procedure is taken in regard to engines. It is thus possible to have a check upon the smallest details if the clerk has time to follow up.

In keeping tabulated records of power station apparatus, it is well to give a single sheet per year to each boiler, engine, generator, or other piece of machinery. Some idea of the compactness of this scheme will be gathered when you see that one sheet, 12 by 15 in., will hold a year's record, complete in the smallest detail. Refer to the record of a water tube boiler as shown by Fig. 2. Five minutes time will show how many tubes were renewed during the year, number of times the boiler was cleaned, and the amount cleaned each time, and show the extent of the repairs on the furnace, these being the principal items of expense. A single glance at a record sheet for an engine, Fig. 3, will show what repairs have been made on valves and valve gear, and only a moment's time is necessary to show the extent of repairs made on cylinders and pistons and on all bearings; then a glance at the space for condensing outfit, and you have a complete idea of that engine's condition. There is absolutely no comparison as regards orderliness and ease of reference between such a systematic record and the old "diary" method of the running engineer, or the prevailing log that is used where any claim is made of keping records, in which case, a great deal of the information wanted is in such shape that it is necessary to read over everything on the log before finding it.

Another system of records which can be made very valuable is that of keeping recording charts, and especially is this useful when the chief has charge of several widely separated stations which it is manifestly impossible for him to visit every day. These charts at once give him an idea of the conditions upon which these plants are operating, and, in many cases, needed adjustments can be made by telephone, instead of by a special visit to the station. Besides the charts usually kept of steam pressure and boiler pressure, a set of charts can be kept showing the work of an economizer, giving temperature of flue gases before entering and when leaving, and giving temperature of feed water entering and leaving the economizer. Then a set could be kept on a condensing outfit, giving the temperature of intake and discharge water, the temperature of hot well and the vacuum produced. This system, besides furnishing a complete record of operation, will give the exact time of any sudden breakdown which might be otherwise forgotten and not recorded. It has the additional value of keeping the men constantly on the alert to keep apparatus in the best condition.

The organization of the power station force is a problem in itself to the chief engineer. Even as the size of the power station increases, so must the inevitable detail increase, and with it the responsibility of the chief, and, since it is manifestly imposible for him to oversee operation in all its detail, he must provide means of dividing the work and still be sure of having all things of importance brought to his attention. Such organization must be made which is consistent with smooth and satisfactory operation and still insure attention being given to all repairs. Another thing upon which the success of any scheme of power station organization depends largely, is the personnel of the operating force, and especially of the engineers. Men of good character and who were considered reliable have been employed about the station, and after repeated instructions persist in placing a wrench on the wrong end of a valve, thereby twisting the valve and making it leak. Or, they will place a monkey wrench backwards on a nut, and strain the wrench and spoil the nut. In tightening the nuts on cylinder heads, steam chest covers, pipe flanges, etc., there is plenty of room for good judgment. Men can be found anywhere to furnish brute strength for work, and who can be made into mere machines, but when you have a man that is wide awake, alive, who can suggest improvements, and who will take time to investigate troubles, instead of blindly applying patches, you have found a jewel indeed. The idea prevails in many places that the engineer and oilers should spend about half their time holding down a good comfortable chair, but in the power station of today all men should be kept as busy as in any shop. As a general rule the average running engineer is not overly progressive, he goes along in the same old way, gets into a rut and out of date, and becomes a machine as truly as those he operates. Such a man, because of this tendency, cannot become the efficient operator or the finished repair man which is necessary in the modern central station. One of the best plans I know of for keeping power plant machinery in good running condition, in a plant which runs 24 hours of the day, is to have three engineers, each on a ten-hour shift. Have one man come on duty, say at 10 a. m. and be relieved by the second man at 8 p. m., while the latter is relieved at 6 a. m. by the head running engineer, who thus runs four hours from 6 to 10 a. m. and has 6 hours remaining to oversee all repair work. By this method he not only can confer with the other two runners as regards behavior of his engines and generators and as to load conditions, but he also becomes very familiar with all station apparatus is right on the job you might say, and has ample time to investigate trouble and suggest remedies and changes. Next to this man should, of course come the boiler room foreman, who has charge of the operation of the boiler room, the fireman and ashmen, as well as repairs on all appliances.

This system gives one man the responsibility of care of the entire station and does not necessarily overtax him since he must confer with his chief upon all important matters.

Fig. 4. gives an idea of the arrangement of the operating force for a power station working from 10 to 40 men.

Fig. 5 shows the force necessary for a system of four stations working all told from 65 to 90 men. Responsibility is definitely fixed and the operating features are essentially the same in all plants; and many of these ideas can be carried out in the small plant as well as in the large one.

The system of keeping a personal record of each employee deserves special mention. The card form shown in Fig. 6 will give some idea of the record found very useful in several ways by the writer. In the first place it gives practically the man's history before entering the company's service. Then it shows the increase in

the man's value to the company by the corresponding raise in his wages or vice versa. It gives the exact time worked by each man for the year by which in the case of a man on monthly salary, his overtime can be computed, and the correct time off duty with full pay be allowed. This card will show every change of address, so that every man can be reached at any time in case of accident. Under "Remarks," merit or demerit notes are made, which may include, as in some cases, the man's conduct while off duty as well as when on. This card is intended to be the medium by which every man's value to the company is computed.

Every man should make out a time check at the end of each day's work.

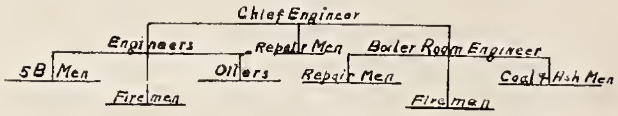


Fig. 4.

On that time check he should tell every kind of work he had done that day, giving the time spent on it, if it was only a half hour. Those time checks would then be taken care of by the clerk who has a list of accounts by which he charges out every item of work, the checks are O. K.d by the engineer, and the general office timekeeper does the rest.

Every power station, no matter how small, can afford to keep a clerk, as he can order material, keep a record of coal, take care of the time of men and the charges on the same, and a number of small things as well as the engineer, and allow the latter to devote his time to more important matters. As the power station grows in size, the numerous different kinds of repair parts and supplies needed require that a record be kept of everything received, which will be so detailed as to furnish complete specifications at any future time for ordering, with but a few moments work in looking up the same.

Then again there are an almost endless number of things which the clerk can adjust by telephone; in fact, there is scarcely any limit to the various details which the wide-awake power-station clerk could take care of. Instead of the old method of giving instructions to heads of departments verbally, important orders can be given in writing, thus avoiding mistakes and accidents. The clerical force could make money for the power station in various ways. For example: It usually costs from $105 to $125 to renew a furnace arch for a 350-h.p. boiler. There are fire brick of various grades, and while records are kept of when arches are renewed, it requires time to follow up records and compare results obtained by the use of different brick. If brick could be found—and they can—which would last twice as long as a poor grade, more than half the expense for renewal of arches would be saved.

Again—there are all kinds of packing upon the market, technical journals are full of advertisements of such goods, and each man will tell you, naturally, that he has the best goods manufactured. The only way for an engineer to judge is by giving them trial, and he loses money by repeated trials if he keeps no records of the performance of different packings under conditions existing in his particular plant. It is possible to keep records of packing as to length of time in service, conditions subject to while in service, etc., from which conclusions may be drawn as to whether first cost of the material really cuts any figure. Which is the cheaper?—to pay $7.00 a pound for packing for making up a joint, $2.00 for packing and $5.00 for labor; or $6.00 per pound per joint, $1.00 for packing and $5.00 for labor, and have the joint last half as long. Such records as the clerical force keeps will tell you that, in the first case, you pay $7.00 for the same period of service which you pay $12.00 for in the second case, thus saving the $5.00 cost of labor and the possible inconvenience resulting from cutting out the steam line. This case is cited to show how easy it is to look at one side of the question, that is, the cost of the packing. In nearly every case the labor cost of making a joint is greater than the cost of the packing, and of course should always be considered and is overlooked by the average purchasing agent.

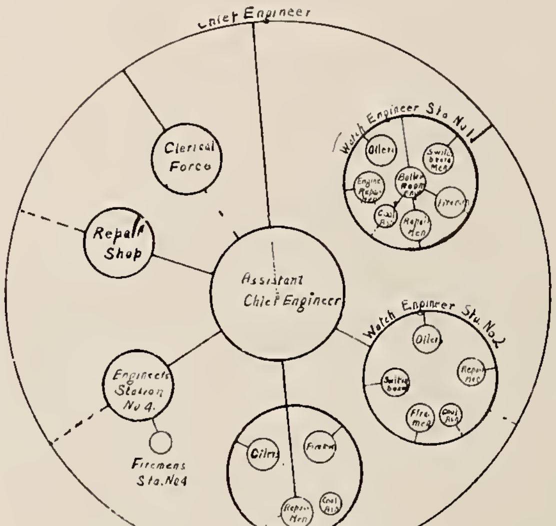


Fig. 5.

Every power station should have a set of rules and regulations for its employees. New men must become familiar with things as they are done in that particular station. The spirit with which the organization receives and instructs a new man has a great deal to do with bringing out the good qualities of the new applicant, and should also act unfavorable in case the party shows such disposition that is known to be a detriment to him as an employee. It sometimes happens that by shifting the party around in a different position or placing him under a different instructor, he makes a good employee. This should be done only when the man has shown some particularly good quality, the engineer believing that he has the making of a good man if properly handled.

Date 1906	Hours Work	Date	Hours Work		REMARKS
Jan.31	100	Jly 15	150	Mch.3	Ran #2 Oil supply tank over on wall and floor. Carlile, running engineer says," do not blame Williams for this as he was called by me very suddenly to help on #2 condenser pump—was having trouble with pump—while he had tank valve open. When I could let him go tank had over-flowed".
31	1?0	31	160		
Feb.15	15?	Aug.15	122		
28	129	31	150		
Mch.15	151	Sept15	155		
31	160	30	150		
Apr.15	140	Oct.15	151	Apl.15	
30	150	31	161	May 15	
May 15	140	Nov.15	147	June 30	
31	150	30	150	Aug.15	Off 10 hours - requested
Jun 15	153	Dec.15	150	31	" 10 " "
30	140	31	164	Nov.15	" 10 " -time allowed " 28 " -on account of sickness " 10 " -time allowed " 3 " - requested

Nov.27 - Find Williams does good bit of reading along steam engineering line, takes "Power", and has few good books on steam engr.& electricity.

Personal Record Card

NAME John D.Williams No.42 Badge No.835 Station No. 2

DUTY Engine Oiler

Date of Birth, January 25,[illegible]	How long out of employment? 5 days
Place of Birth, [illegible], Ky.	By whom last employed? Mt.Pleasant
Married, No	Lumber Co.Mt.Pleasant,Ky.
Raised, at place of birth	For how long? 2 1/2 yrs., then with
Residence, 218 East Gay St.	Marion Light & Pr.Co.Marion,Ky, for
7-7-06 84 West First Ave.	16 months.
	Why did you leave? To takeplace in
	Larger station.
Trade or occupation --	Ever employed in Power Station Work?
Recommended by, C.N.Hoaglan,C.E.	Yes, See above.
Marion Light & power Co., who says	Where and what capacity? As oiler
"a willing, careful, studious and	In above.
ambitious boy".	Ever in strike or riot? No.
	Member Secret Society? Odd Fellows
General description:	Date Instruction commenced, Jan.22,06
	Instructor, R.D.Brown
	entered the service, Jan.22,1906.
	Left the Service,
	Cause,
	Rate, 17 1/2c per hr.
Signature, J.D.Williams	6/1/06 - 19 c per hr.

Fig. 6. 7"

Fig. 6.

A new method of preserving poles is being exploited by the Universal Pole & Post Preserving Co. As described by H. P. Folsom before the Association of Railway Telegraph Superintendents, June 26th, the method consists in packing around the pole at the ground a mixture of rock salt, hydrated lime and a small quantity of copper sulfate with coarse sand. These chemicals slowly dissolve and filter through the wood, destroying, so it is said, the fungus growth which cause rotting of the wood. The ordinary method of treatment is to dig a 14-in. hole around the pole and clean off the rot to this depth. Then a 14-in. asbestos collar is put around sufficiently large to hold the chemical mixture, after which the whole is capped with Portland cement to protect it from the weather. It is claimed that poles treated in this manner nine years ago are in good condition and that the cost is 75 cents to $1 per pole.

Meter Testing

The fact that a man has tested a few meters does not make him a meter tester.* An efficient and reliable tester must devote time and thought to the study of meter problems, and he must understand the reasons for meter troubles and the best methods of correcting them. He must, in fact, have acquired a facility in testing and calibrating, obtained only by a more or less extended experience. A manager will find it more advantageous to employ a thoroughly efficient and reliable meter tester for his meter work, utilizing his spare time, for instance, on arc lamps, and the like, rather than to employ an arc-light man, and utilize his spare time on meter work, as often seems to be done.

Meter tests may be classified as follows:

Shop tests.
Installation tests.
Periodic tests.
Complaint tests.
Inquiry tests.
Re-tests.
Repair tests.
Special tests.

Shop Tests. — Experience has shown that when meters are received from the manufacturer they are sometimes not in calibration and occasionally have become damaged in transportation and handling. The meters should therefore be inspected, tested and calibrated in the shop before being placed in stock.

The meters should be carefully examined, and any mechanical defects that will prevent their proper operation should be eliminated. The constants should be checked, and the insulation should be tested to see that none of the circuits are grounded on the meter frame and the like. The meter should be tested and calibrated on both light and full loads to ascertain that the meter can be properly adjusted. Induction meters should be tested to ascertain if they are properly quarter-phased and will register accurately on non-inductive loads and also on inductive loads of 50 to 70 per cent. power-factor.

All meters removed from service should receive a shop test before again being placed in stock.

Installation Tests.—Experience has demonstrated that even though a meter is properly tested in the shop it is not always safe to consider that it will remain in calibration during transportation and erection, and therefore an installation test or inspection is imperative.

In the case of commutator meters a test is imperative. Some companies prefer to send an inspector within a day or so after the meter is installed, to determine if the meter is properly connected and if it will register on one lamp, and so on, and after about two to four weeks a tester is sent to test and calibrate the meter. The reason for this procedure is that the commutator is expected to have become properly aged during this interval. Other companies prefer to test the meter within a few days after its installation. One of the advantages claimed for the latter method is that short-circuits and accidents that affect the accuracy of meters frequently occur on new installations, and that such accidents may affect the accuracy of the meter to a greater degree than does the aging of the commutator.

Induction meters should be tested as soon after their installation as possible.

The meter departments of some companies not only test but "set" the meters, and some of these companies consider that only an inspection is necessary on induction meters.

The advantages of testing meters after installation is that the meters are calibrated under the conditions that obtain in actual service.

Periodic Tests.—A meter cannot be expected to remain in calibration for an indefinite period. The jewel is apt to become roughened, and short-circuits and other causes may seriously affect the acuracy. It is therefore customary to test meters periodically. Periodic tests are made at intervals of 1, 3, 6, 12, 18 months, and so on, depending upon circumstances. Commutator meters are generally more liable to become inaccurate than induction meters, due to the heavier weight of moving element and to the friction of the commutator and brushes, and therefore should generally be tested more often than induction meters.

Some companies test monthly all large meters that register very large amounts, for the reason that the kilowatt-hours corresponding to, say, a 1 per cent. error in the large meters, more seriously affects the revenue than a much larger percentage error in smaller meters.

The amount registered, however, is not the only determining factor in deciding upon the period between tests; for, while some meters may not require testing until the disc has rotated from 500,000 to 1,000,000 or more revolutions, others may require more frequent testing, due to excessive vibration or other local causes.

While no rule can be formulated that will definitely fix the interval between periodic tests of different capacities of meters and for classes of business, yet it may be assumed as evident that each meter should be tested and calibrated before its maximum error exceeds the limits of commercial accuracy.

The following is a tentative method of determining period between tests:

A list should first be made of all large meters registering large amounts. These meters should be tested at intervals of, say, three months. If the meters are found to be much in error the interval should be reduced to two months or one month; if the meters are accurate the interval may be extended to four, five or six months, until the maximum period during which the meter will remain in calibration is determined.

This system, followed for other capacities of meters and classes of business, will approximately determine the periods between tests.

Some companies use a schedule about as follows:

Commutator Meters.
110-220 volts:
Meters in residences are tested yearly.
Meters in business premises are tested semi-annually or at shorter intervals.
500 volts:
Meters are tested every two to four months.

Induction Meters.
Meters in residences are tested at intervals of one or two years.
Meters in business premises are tested yearly or at shorter intervals.

It must be remembered that no schedule, as above, can be followed absolutely, as local conditions may require the removal of a meter from the annual to the semi-annual class, or *vice versa,* and so on.

Complaint Tests.—When a consumer complains of his bill, it is frequently customary to test the meter unless a test has been very recently made. Complaint tests are conducted in the usual manner, except that it is customary to test the meter, not merely on light and full load, but also on other loads, especially on the normal load or load most generally used, as this information is of great assistance in determining whether the bill is correct or otherwise.

Inquiry Tests.—Inquiry tests are tests ordered by the company itself, before the bill is rendered, to determine whether or not the meter has been operating properly. These tests are usually ordered by the billing department, upon noting a sudden rise or drop in the amount of the bill for any month.

*N. E. L. A., 1909.

Check Tests.—It is becoming more and more customary to delegate one of the most experienced testers to test meters that were calibrated the preceding day by one of the regular force; the object of this procedure being to determine the efficiency of the various testers and to ascertain in what condition they left the meters.

Re-Tests.—Re-tests are tests made before current is reintroduced on meters which have been out of commission for a long time; or, if a meter has been opened by any one other than an authorized meter tester; or if the meter has been moved or re-connected while in service, and so on.

Repair Tests.—These are tests made on meters that have been repaired in service. These tests should be made immediately after the repairs have been completed.

Special Tests.—Under this heading may be included all other tests, such as tests conducted on meters to determine the period during which they will operate within the limits of commercial accuracy, and any other experimental tests, and the like, not included in the above list.

Testing Loads.—When testing meters, it is usually customary to test direct-current meters on loads equivalent to 10 per cent. and 50 to 100 per cent. of the rated capacity of the meter, and induction meters on 5 per cent. and 50 to 100 per cent. of their rated capacity—about 75 per cent. being considered preferable for full-load tests. Some companies test meters on 5, 25, 50 and 100 per cent. loads, and so on, while others test on three loads, *viz.*, light load, full load and normal load, and this is compulsory in some states. The law also requires that three readings shall be taken on each of these three loads.

When calibrating both commutator and induction meters on large or full load, the accuracy should be between 99 and 101 per cent., and as near 100 per cent. as practicable.

When calibrating induction meters on light load, it is customary to obtain an accuracy ranging from 98 to 101 per cent.

When calibrating commutator meters on light load, it is usually impossible to obtain an accuracy as great as 100 per cent. without sacrificing brush tension, thus affecting the permanency of calibration. In general, 98 per cent. might be considered a maximum.

Commercial Accuracy.—When meters are tested in service and the average accuracy falls between 95 and 105 per cent., inclusive, *i. e.*, 5 per cent. plus or minus, the meter should be considered commercially accurate.

METHODS OF TESTING.

Shop Method.—For testing meters in the shop, it is customary, particularly with the larger companies, to install special switchboards and apparatus for performing this work with the maximum efficiency and the minimum amount of labor. It is customary to make permanent arrangements to obtain the requisite voltages and currents, and special racks are provided, upon which one or more meters may be erected and calibrated at the same time.

In very large companies it is usually customary for one attendant to operate the switchboard and, by the use of rheostats, and the like, maintain the exact current and voltage required, while the testers adjust and calibrate the meters. By this means, from 15 to 25 meters may be tested per day by each tester.

SERVICE METHODS.

For the testing of meters in service, three general methods are in use, *viz.*: (1) Standard Instruments, (2) Standard Resistance, and (3) Rotating Standards.

Standard Instruments for Direct Current.

For testing direct-current meters, it is customary to use a voltmeter, a portable millivoltmeter with shunt, or an ammeter, and a stop-watch.

Voltmeter.—For testing meters on the Edison three-wire system, the voltmeter should preferably have two scales—one indicating from 0 to 150 volts, and the other from 0 to 300 volts. As voltmeters are usually calibrated to give the greatest acuracy at the point most used—say from 110 to 115 volts, and from 220 to 240 volts—it is advisable to use the scale best suited to the voltage to be measured. The leads of the voltmeter should preferably be connected to the circuit as near as possible to the points at which the potential leads of the integrating meter are connected.

Millivoltmeter. — Millivoltmeters with shunts are calibrated to read in amperes. The instrument that seems to be most used has 150 divisions on the scale; and the shunt box contains three shunts marked 1.5, 15 and 75 amperes, therefore the divisions on the scale for each ampere are 100, 10 and 2, respectively.

This shunt box is suitable for meters of capacities not exceeding 100 amperes. For larger meters, a separate shunt box, having a larger range, is used. The shunt box is connected in series with the field coils of the meter by leads fastened to the binding posts on the current side of the shunt box; and the millivoltmeter is connected to the instrument side of the box by the special leads, which are furnished with, and have the same number as, the instrument, and under no conditions should any other leads be used or the lengths of the leads be changed, as errors may be introduced.

When changing connections for increasing or decreasing the load, it is found desirable to disconnect the instrument from the shunt-box, as a short circuit or overload, which would not affect the shunt when the instrument is disconnected, may bend the pointer of the instrument and burn out the small coils in both the shunt-box and the instrument when the latter is connected. It is advisable, where the neutral is grounded, to cover the instrument leads with rubber tubing, as, at times, incorrect readings have resulted, due to leakage when the leads have come in contact with the ground, and the like.

When testing meters in districts where the neutral is grounded, it is also desirable, where possible, to connect the neutral wire to the shunt, as, under these conditions, no short circuits will result if the terminal of the instrument lead makes contact with the ground.

Ammeters.—Ordinarily, it is not desirable to use ammeters for testing meters, on account of the possible inacuracy of the results. If direct-current ammeters are left in circuit for any length of time, errors are introduced, due to heating; and while errors are small in low-capacity instruments, they are quite large in the larger capacities. When ammeters are used, especially the larger capacities, it is advisable to connect in circuit a short-circuiting switch, and shunt the ammeter except during the time that readings are taken.

Ammeters of 25 amperes capacity and less have been used to some extent, and with fair results; but it is evident that the accuracy of the results obtained, when testing meters on light loads with ammeters of full-load capacity, cannot be favorably compared with the results obtained by the use of a millivoltmeter with shunt, where 100 divisions correspond to one ampere.

Three separate ammeters would be required to secure the same range as with the millivoltmeter and shunt mentioned above, and even then the results with the millivoltmeter would be superior, as heating errors in millivoltmeters are practically negligible.

Stop-Watch.—The stop-watch used should be thoroughly reliable, and it is generally considered that a chronometer having a sweep second-hand is more desirable than the ordinary stop-watch. The latter will sometimes throw the hands forward or backward an appreciable fraction of a second on the start, and unless the meter is timed for, say, 40 seconds, this may introduce an error of several per cent. Too much care cannot be

exercised in the selection of the type of stop-watch to be used, nor can too much care be exercised in checking it and keeping it accurate.

Standard Instruments for Alternating Current.

For testing meters on alternating-current circuits, the instruments most used are indicating wattmeters and stop-watches. Sometimes standard lamps and voltmeters are used for for testing on light loads, but it is becoming the custom to construct the indicating wattmeters with two scales —one for testing on light loads and the other for testing on full loads.

Standard Lamps, Etc.—The use of standard lamps for service testing is frequently attended with considerable error. Small standard resistances and voltmeters have been used for testing on light loads, and, if the resistances are properly constructed, they are far superior to standard lamps.

Ammeters and Voltmeters.—Ammeters and voltmeters only should never be used for testing meters on alternating-current circuits, as frequently there is inductance in the circuit, and the volt-amperes thus obtained may not represent true watts. Furthermore, the alternating-current ammeters are usually less reliable than even the direct-current ammeters.

Indicating Wattmeters.—The indicating wattmeter, when properly connected, is a very reliable instrument. It lacks, however, the advantages of the scale ranges of the millivoltmeter with shunts, as the wattmeter is usually constructed for one capacity only, except the more modern instruments, which have two scales. The wattmeter indicates true watts, and not necessarily volt-amperes; it is, therefore, the only instrument suitable for testing meters on alternating-current circuits.

It is customary to provide wattmeters of various capacities; as, for instance, 10-ampere instruments for testing 5 to 10-ampere meters; 25-ampere instruments for testing 15 to 25-ampere meters, and so on. Indicating wattmeters are usually constructed for but two voltages—150 and 300 volts—and multipliers are required for higher voltages. As the capacity in amperes and volts is limited, care must be exercised that neither of the limits is exceeded, as otherwise the instrument may be burned out.

When testing on inductive loads, it is sometimes desirable to use an ammeter in connection with the wattmeter, merely to prevent an overload of the indicating wattmeter.

When testing meters with the indicating wattmeter, the potential leads of the instrument should be connected to the circuit as near as possible to the points at which the potential leads of the meter are connected. Care must be taken, however, that the meter does not record the losses in the potential circuit of the instrument, and *vice versa.* This is especially necessary on light loads, as these losses have a greater influence on the test at light load than at full load.

As most alternating-current instruments, with the possible exception of the so-called iron-clad instruments, are susceptible to the influence of external fields, it is very desirable that they should not be brought within the influence of such fields during the test. It is also desirable that the position of the instrument should not be changed during the test.

Load

While some companies use the various lamps, and the like, installed in the premises for obtaining the necessary loads for testing meters, this is usually considered inconvenient for both the consumer and the tester. It is customary to use a portable form of resistance, such as lamp banks, load boxes, water rheostats, and the like. The load for testing very large direct-current meters is frequently obtained by the use of portable cells of storage battery and the current is regulated by carbon rheostats or other suitable form of resistance.

Some companies use a small portable transformer for testing alternating-current meters, but such transformers, unless properly constructed and properly used, may introduce a large error.

For testing 500-volt direct-current meters, a small storage battery with suitable resistance is frequently used for supplying current, and is found to be more desirable than the use of lamp banks, and the like. Indicating wattmeters (alternating and direct-currents) should not be used for the testing of meters on direct-current circuits, as the results obtained are usually far from acurate.

Standard Resistances.

The standard resistance method of testing meters consists of the employment of a voltmeter, a stop-watch, and a specially constructed resistance, calibrated in amperes or watts for various voltages, the corresponding values being tabulated. The resistances are carefully calibrated in the shop or laboratory and are usually constructed to be available for testing meters on both alternating and direct-current circuits; in other words, the inductance is small.

This resistance must be constructed of a suitable zero temperature metal, so as to obviate temperature errors. The resistance is connected across the line and in series with the field coils of the meter to be tested. It is necessary to use leads sufficiently large between the meter and the resistance to prevent any errors due to drop, poor connections, and the like. The voltmeter is connected to the circuit as near as possible to the points at which the potential leads of the meter are connected. As the resistances have several units of different load values, each controlled by a switch, in order to obtain the standard watts it is only necessary to note the units connected, ascertain the voltage, and read the wattage corresponding to this voltage as indicated on the tabulation. Various forms of resistance are employed.

This method of testing is usually employed for the smaller sizes of integrating meters, and the load boxes are so constructed as to permit of the testing of the meter on both light and full loads.

When employing this method, it will be seen that only one instrument —a voltmeter—is required, and, therefore, many companies consider that only one man is necesary for testing the meters.

Rotating Standards.

The method of testing integrating meters by employing rotating standards is becoming more and more used. The rotating standards are integrating wattmeters especially constructed for testing other meters. They are usually made for several capacities, such as 1, 10, 20, and so on, amperes, and 110 and 220 volts. Means are provided for quickly starting and stopping the standard meter, and the dial ordinarily reads in revolutions. The rotating standards thus far manufactured have usually not exceeded 100 to 150 amperes in capacity, and the standards are therefore not used for testing the larger capacities of meters. The advantage of using the rotating standards are so many that they have largely superseded the standard instrument and the standard resistance method, some companies employing them almost entirely. Among these advantages may be mentioned the following:

1. Only one instrument is required, namely, the rotating standard. Indicating voltmeters and wattmeters are unnecessary; also stop-watches, unless it is desired to know the exact load on the meter, or to insure that the period of timing shall extend over a predetermined number of seconds. This method of testing is applicable to meters on both direct and alternating-current circuits.

2. The standard and the meter under test are subjected to the same conditions, therefore no variation in voltage or current need be taken into consideration. If the load is fluctuating rapidly, the standard meter furnishes

the most practical method of testing meters.

3. As the standard meter is the only instrument required, it is possible to test meters with one man.

4. More meters can be tested per day per man than with indicating instruments.

5. As rotating standards are more rugged than indicating instruments, the cost of repairs and re-calibration is less.

The method of testing with the rotating standard is as follows: The field coils of the standard are connected in series with the field coils of the meter, and the potential leads of the standard are connected to the circuit as near as posible to the point at which the potential leads of the meter are connected. It is only necessary to count a certain number of revolutions of the meter and then note the reading of the standard. The watt-hours or watt-seconds of the meter divided by the watt-hours or watt-seconds of the standard determines the per cent. fast or slow of the meter. It will be seen that this method is very simple.

Many companies use only one man for testing meters with a rotating standard, while others employ two, especially when testing large meters, or where the company loses, by resignation, advancement, or the like, so many of its testers as to require the continual education of new men.

THE WORK OF TESTING.

When meters are tested and calibrated by one man only, namely, the tester, he must of course perform all the work of reading the standards, making the necessary adjustments, and the like. When a team, consisting of a tester and an assistant, performs the work, it is usually customary for the assistant to read the standard instruments and for the tester to make the adjustments on the meter. Some companies permit the assistant to perform the work of adjusting; but this policy is questionable, for the reason that the continued accuracy of the meter depends very largely upon the skill with which the adjustments are made, and it is preferable that the more experienced man should perform the more difficult work. After the test before adjustment, some companies permit the assistant to make preliminary adjustments for the purpose of perfecting his education; the tester supervising his methods and later making the final adjustments.

The tester should be supplied with additional jewels, pivots, top bearings, and the like, for replacing those that are unfit for service, and should preferably make any small repairs. For any large repairs, however, it is customary either to send the meter back to the shop; if the repairs are not too extensive, some companies are adopting the method of sending a man from the shop to make these repairs, later having a tester calibrate the meter. This method frequently results in a saving of time and expense.

The following general remarks may be found of assistance:

The tester should examine the meter and the installation to see that the seal is intact and that the wiring is in proper condition, and so on. Anything found wrong may have affected the registration of the meter, and may account for any difference in previous and subsequent bills. It is desirable always to take the statement of the dials, as in the event of the register being later removed it can be reset to the original reading, etc.

The cover should then be removed, and the testing instruments should be properly connected in circuit without in any way disturbing the condition and adjustments of the meter.

The meter should then be tested on both light and full load to determine its accuracy, as previously explained. Under special conditions it may be desirable to test a meter at other points, especially if the meter has operated on less than a 5 or 10 per cent. load, or has operated on an overload, and the like. This test is usually designated the "test before adjustment" or the "test as found," and it indicates the accuracy with which the meter has been operating. It is never advisable to take merely one reading, as fluctuations may occur that will affect the accuracy of the test. Three or more readings should be taken, and the readings should practically agree with one another.

The meter should then be properly inspected, cleaned, adjusted and calibrated, as may be required. The final readings should be verified, as above. This final test is usually termed the "test after adjustment" or the "test as left." The instruments should then be disconnected, the meter reconnected, and the cover replaced. The dials should again be read and the statement compared with the original reading. It will then be found desirable to turn on a few lights to see that the meter will operate, as sometimes switches have been left open, fuses left out, and the like, which have subsequently caused the consumer to complain.

In the case of commutator meters, it will be found that after a new meter has been in operation for a few weeks the commutator becomes discolored and presents a somewhat glazed appearance, or is "aged." A commutator, when so aged, will continue in this condition for a long time, and it is in a more serviceable condition for operation than if newly cleaned. It is, therefore, never advisable to clean a commutator unless its condition absolutely requires it, due to sparking or other causes.

If two or more segments of the commutator are short-circuited, the meter will be found to register too low throughout its entire range, and it will be necessary to remove the cause (which may be a small piece of metal lodged between the commutator segments) with a small stick. Dust on the commutator, and the like, can usually be removed by the use of a rubber syringe, which makes a very effective blower. It is usually customary to clean commutators with a suitable piece of tape, and in case the commutator is very rough, due to sparking, a piece of worn crocus cloth is sometimes used.

The brushes should be carefully adjusted to bear uniformly upon the commutator, and the tension also should be properly adjusted. If the tension is too strong the meter may run slow, and if too light there may be sparking. The proper adjustment of brushes requires considerable experience.

Care should be exercised in handling the register, as small burrs may be raised on the teeth, which may materially affect the accuracy of the meter. The tester should see that the gearing is clean and runs without undue friction.

Both direct and alternating-current meters are provided with a suitable device for compensating for static friction. Care must be exercised in the adjusting of this device to see that the meter is not overcompensated.

The adjustment of the magnets affects the accuracy of the meter throughout its range, and after the magnets have been adjusted it is imperative to check the meter on light loads. It is, in fact, always desirable to check the meter on both loads after any adjustment of any kind has been made.

A chattering in meters, due to vibration of the top bearing in the top-bearing stud, sometimes occurs. This can usually be corrected by applying a film of the finest watch oil on the top bearing; although, at the present time, many manufacturers are furnishing a top-bearing stud containing a spring which takes up any vibration of this character.

The Cutler-Hammer Mfg. Co., of Milwaukee, makers of electric controlling devices, announces the opening of a Philadelphia office, Room 1207 Commonwealth Building, and an engineer specially qualified to advise regarding the control of electric motors will be in charge of the new office.

Results of Purchasing Coal Under United States Government Specifications

Since the government has been purchasing coal on the basis of its heating value a growing interest has been manifest in this important subject and a demand has been created for authentic information concerning the results accomplished. In response to this demand the results of the government's purchases of coal under the heat-value specifications for the fiscal year 1907-8 have been assembled by J. S. Burrows in a report to the United States Geological Survey.

The United States Government purchases annually from $6,500,000 to $7,000,000 worth of fuel. This includes the cost of delivery and in many cases the cost of stowage. Each department purchases the coal through the purchasing officers of its respective bureaus. The Navy, War, Treasury, Interior, and Commerce and Labor departments are the larger consumers of coal in the aggregate.

Most of the coal purchased is used for warming public buildings and for power purposes, though small quantities of blacksmith's or forge coal and coke are bought. The larger individual contracts are for bituminous coal and the small sizes of anthracite; the larger sizes of anthracite are, as a rule, purchased in small lots and delivered mainly by wagons.

NATURE OF SPECIFICATIONS.

Government specifications are drawn with a view to the consideration of price and quality. For manufactured articles and materials of constant and uniform quality they generally can be reduced to a clear statement of what is desired. For coal, however, the variation in character makes this impracticable.

This lack of uniformity is the feature recognized and provided for in the coal specifications prepared by the Geological Survey. Under these specifications, bidders are requested to quote prices on the various sizes of anthracite, a definite standard of quality being specified for each size, and to furnish the standard of quality with price for bituminous coal offered. Awards are then made to the lowest responsible bidder for anthracite and to the bidder offering the best bituminous coal for the lowest price. The specifications become part of the contract, and the standards of quality form the basis of payment for coal delivered during the life of the contract. For coal delivered which is of better quality than the standard, the contractor is paid a bonus proportional to the increased value of the coal. For deliveries of coal of poorer quality than the standard, deductions are made from the contract price proportional to the decreased value of the coal. The actual quality and value of coal delivered is determined by analysis and test of representative samples taken in a specified manner by agents of the government and analyzed in the government fuel-testing laboratory at Washington. The necessity of paying for coal on a sliding scale was fully discussed by D. T. Randall in a recent paper.*

The advantages of this system of purchasing coal may be briefly summarized as follows:

(1) Bidders are placed on a strictly competitive basis as regards quality as well as price. This simplifies the selection of the most desirable bid and minimizes controversy and criticism in making awards.

(2) The field for both the Government and dealers is broadened, as trade names are ignored and comparatively unknown coals offered by responsible bidders may be accepted without detriment to the Government.

(3) The Government is insured against the delivery of poor and dirty coal, and is saved from disputes arising from condemnation based on the usual visual inspection.

(4) Experience with the old form of government contract shows that it is not always expedient to reject poor coal, because of the difficulty, delay, and cost of removal. Under the present system rejectable coal may be accepted at a greatly reduced price.

(5) A definite basis for the cancellation of contract is provided.

(6) The constant inspection and analysis of the coal delivered furnishes a check on the practical results obtained in burning the coal.

HISTORY OF BUYING COAL FOR GOVERNMENT USE UNDER SPECIFICATIONS

To receive consideration bids must be based upon the following percentages of ash for the various classes of coal:

	Per cent of ash in dry coal.
Furnace	10
Egg	10
Stove	12
Chestnut	14
Pea	16
Buckwheat No. 1	18
Buckwheat No. 2	18

Coal with less ash than the standard will be paid for at a higher price and vice versa, in accordance with the provisions for payment.

Samples of the coal delivered are taken by a representative of the Government.

Wherever practicable the coal is sampled at the time it is being delivered to the building. In case of small deliveries, it may be necessary to take these samples from the yards or bins. The sample taken is in no case less than the total of one hundred (100) lb., to be selected proportionally from the lumps and fine coal, in order that it will in every respect truly represent the quantity of coal under consideration.

In order to minimize the loss in the original moisture content the gross sample is pulverized as rapidly as possible until none of the fragments exceed one-half inch in diameter. The fine coal is mixed thoroughly and divided into four equal parts. Opposite quarters are thrown out, and the remaining portions thoroughly mixed and again quartered, throwing out opposite quarters as before. This process is continued as rapidly as possible until the final sample thus obtained will be contained in the shipping can or jar and sealed air-tight.

The sample is forwarded to the chemical laboratory.

If desired by the coal contractor, permission will be given to him, or his representative, to be present and witness the quartering and preparation of the final sample to be forwarded to the government laboratories.

Immediately on receipt of the sample it is analyzed and tested by the government according to the method adopted by the American Chemical Society, which involves the use of a bomb calorimeter. A statement of the result is mailed to the contractor on the completion of the test.

It is understood that the coal delivered during the year will be of the same character as that specified by the contractor.

Coal containing more than 1 per cent. of sulphur, an excessive amount of dust and fine coal, or a percentage of ash in excess of the maximum limits, indicated in the following table, is subject to rejection:

	Per cent.
Furnace coal	14
Egg coal	14
Stove coal	16
Chestnut	18
Pea	20
Buckwheat No. 1	21
Buckwheat No. 2	21

PRICE AND PAYMENT

Payment will be made on the basis of the price named in the proposal for the coal specified, corrected for variations in ash as shown by analysis above and below the standard as indicated by the following tables:

* The purchase of coal under government and commercial specifications on the basis of its heating value: Bull. U. S. Geol. Survey No. 339, 1908

With respect to delivery and sampling, the bituminous coal specification is essentially the same as that for anthracite. The description of the coal desired is given by the government for each contract, in the blanks provided on the form, and maximum amounts of ash, voltaile matter, sulphur, dust, and fine coal (through one-eighth inch round-hole screen) are specified.

The remaining and important parts of the specification are as shown below.

A contract entered into under the terms of this specification is binding if, on practical service test of reasonable duration, the coal fails to give satisfactory results by reason of excessive clinkering, or a prohibitive amount of smoke.

It is understood that the coal delivered during the year will be of the same character as that specified by the contractor. It should, therefore, be supplied, as nearly as possible, from the same mine or group of mines.

Coal containing percentages of volatile matter, sulphur, and dust higher than the limits indicated in the specifications, and coal containing a percentage of ash in excess of the maximum limits indicated in the following table, is subject to rejection.

For coal which has been delivered and used for trial, or which has been consumed or remains on the premises at the time of the determination of its quality, payment is at a reduced price, computed under the terms of this specification.

Occasional deliveries containing ash up to the percentage indicated in the column of "Maximum limits for ash," may be accepted. Frequent or continued failure to maintain the standard established by the contractor, however, will be considered sufficient cause for cancellation of the contract.

Payment is made on the basis of the price named in the proposal for the coal specified therein, corrected for variations in heating value and ash, as shown by analysis, above and below the standard established by the contractor in this proposal. For example, if the coal contains 2 per cent. more or less British thermal units than the established standard, the price will be increased or decreased 2 per cent. accordingly.

The price will also be further corrected for the percentage of ash. For all coal which by analysis contains less ash than that established in this proposal a premium of 1 cent per ton for each whole per cent. less ash will be paid. An increase in the ash content of 2 per cent. over the standard established by contract will be tolerated without exacting a penalty for the excess of ash. When such excess exceeds 2 per cent. above the standard established, deductions will be made from price paid per ton in accordance with the following table:

Corrections in prices of coal on account of variations in per cent of ash from the standard in dry coal.

FURNACE AND EGG.

Per cent of ash in dry coal.								
6.01 to 6.50	6.51 to 7.00	7.01 to 7.50	7.51 to 8.00	8.01 to 12.00 inclusive.	12.01 to 12.50	12.51 to 13.00	13.01 to 13.50	13.51 to 14.00
Cents per ton to be added.				Standard contract price.	Cents per ton to be deducted.			
24	21	18	15		15	18	21	24

STOVE.

Per cent of ash in the dry coal.										
7.51 to 8.00	8.01 to 8.50	8.51 to 9.00	9.01 to 9.50	9.51 to 10.00	10.01 to 14.00 inclusive.	14.01 to 14.50	14.51 to 15.00	15.01 to 15.50	15.51 to 16.00	16.01 to 16.50
Cents per ton to be added.					Standard contract price.	Cents per ton to be deducted				
27	24	21	18	15		15	18	21	24	27

CHESTNUT.

Per cent of ash in the dry coal.									
9.51 to 10.00	10.01 to 10.50	10.51 to 11.00	11.01 to 11.50	11.51 to 12.00	12.01 to 16.00 inclusive.	16.01 to 16.50	16.51 to 17.00	17.01 to 17.50	17.51 to 18.00
Cents per ton to be added.					Standard contract price.	Cents per ton to be deducted.			
27	24	21	18	15		15	18	21	24

PEA.

Per cent of ash in the dry coal.										
12.51 to 13.00	13.01 to 13.50	13.51 to 14.00	14.01 to 14.50	14.51 to 15.00	15.01 to 17.00 inclusive.	17.01 to 17.50	17.51 to 18.00	18.01 to 18.50	18.51 to 19.00	19.01 to 19.50
Cents per ton to be added.					Standard contract price.	Cents per ton to be deducted.				
15	12.5	10	7.5	5		5	7.5	10	12.5	15

BUCKWHEAT

Per cent of ash in the dry coal.											
14.51 to 15.00	15.01 to 15.50	15.51 to 16.00	16.01 to 16.50	16.51 to 17.00	17.01 to 19.00 inclusvie.	19.01 to 19.50	19.51 to 20.00	20.21 to 20.50	20.51 to 21.00	21.01 to 21.50	21.51 to 22.00
Cents per ton to be added.					Standard contract price.	Cents per ton to be deducted.					
12	10	8	6	4		4	8	14	21	32	48

An important point which seems not to be thoroughly understood in purchasing coal on the basis of its heating value is the manner of making awards. In order to show how the lowest bid is determined, the proposals for sup-

Ash as established in proposal (per cent).	No. deduction for limits below—	Cents per ton to be deducted.							Maximum limits for ash (per cent).
		2	4	7	12	18	25	35	
		Per cent of ash in dry coal.							
5	7	7–8	8–9	9.10	10–11	11–12	12.13	13–14	12
6	S	8–9	9–10	10–11	11–12	12–13	14–13	14–15	13
7	9	9–10	10–11	11–12	12–13	14–13	14–15	15–16	14
8	10	10–11	11–12	12–13	13–14	14–15	15–16	16–17	14
9	11	11–12	12–13	13–14	14–15	15–16	16–17	17–18	15
10	12	12–13	13–14	14–15	15–16	16–17	17–18	....	16
11	13	13–14	14–15	15–16	16–17	17–18	18–19	....	16
12	14	14–15	15–16	16–17	17–18	18–19	19–20	....	17
13	15	15–16	16–17	17–18	18–19	19–20	20–21	....	18
14	16	16–17	17–1S	18–19	19–20	20–21	21–22	....	19
15	17	17–18	18–19	19–20	20–21	21–22	....	....	19
16	18	18–19	19–20	20–21	21–22	22–23	....	....	20
17	19	19–20	20–21	21–22	22–23	....	....	....	21
18	20	20–21	21–22	22–23	....	....	....	....	22

plying coal to the federal buildings under the Treasury Department have been selected as representing the widest range of coals and conditions throughout the country.

All bids are received on official proposal blanks, in sealed envelopes, in response to advertisements inserted in the daily papers. These proposals are opened at a specified time, in the presence of all those who desire to attend, and awards are made as soon thereafter as possible.

In order to make a proper award of contract it is necessary to reduce the proposals to one common basis for comparison. This may be done in several ways, but the method chosen in this case is to first adjust all bids upon a given lot of coal to the basis of the same ash percentage by selecting the proposal which contains the lowest percentage of ash as the standard. Each per cent. of ash content is assumed to have a value of 2 cents per ton, the amount of penalty which is exacted under the contract requirements for 1 per cent. deficiency. The proposal prices have all been adjusted in this manner and are tabulated in the table. On the basis of the adjusted price, allowance is then made for the varying heating values by computing the cost of 1,000,000 British thermal units. In this way the three variables of calorific value, percentage of ash, and basic price per ton are all merged into one figure, the comparative cost of 1,000,000 British thermal units, by which one bid may be readily compared with another.

For example, take two bids received for coal in Boston, Mass., as follows:

Bid.	Coal.	British thermal units.	Per cent ash.	Price per ton.
A	New River	14,658	5.11	$4.73
B	Pocahontas	14,600	S.00	5.10

The percentage of ash in A is taken as a standard of comparison and the ash in B determined as 2.89 per cent. higher. Each per cent. of ash difference from the contract standard is rated at 2 cents difference in price per ton; 2.89 per cent. of ash is valued at $\$0.02 \times 2.89$ or \$0.0578; B is therefore increased to \$5.1578 per ton. The two bids are then on an equivalent basis, so far as ash is concerned, as follows:

Bid.	British thermal units.	Price per ton.
A	14,658	$4.73
B	14,600	5.1578

The heating values being different, it is desirable to compute the cost of 1,000,000 B.t.u. in each case by the formula:

$$\frac{1{,}000{,}000 \times \text{price per ton}}{2240 \times \text{B.t.u.}}$$

In the case of A this gives

$$\frac{1{,}000{,}000 \times \$4.73}{2240 = 14{,}658} = \$0.14406,$$

and in the case of B gives

$$\frac{1{,}000{,}000 \times \$5.1578}{2240 \times 14{,}600} = \$0.15771,$$

the results being the cost of 1,000,000 B.t.u.

The necessity for having such a basis of comparison is evident from an examination of the bids for coal to be delivered in St. Louis. In this case seven bids were received with guaranties of British thermal units from 10,500 to 12,061 and of ash from 7.74 to 16.75 per cent., while the prices ranged from \$2.04 to \$2.53 per ton. Notwithstanding such apparent discrepancies, the comparative cost of 1,000,000 B.t.u. ranged only from 9.0149 to 9.8831 cents.

Another interesting case appears as the result of the competition in Philadelphia, in which 16 proposals are based on heating values ranging only from 13,500 to 14,500 and on ash from 5 to 8 per cent., with prices more variable and ranging from \$3.14 to \$3.98 per ton. Two of these proposals appear nearly equally advantageous, and the relative suitability of the two coals for use in the down-draft furnace with which the boilers are equipped will be determined by actual trial of a test quantity of 50 or more tons.

In eight cases out of 23 it was found more advantageous to award the contracts to bidders other than the lowest if price per ton alone were considered.

An examination of the table should dispel any doubt as to the general applicability of the specifications to a wide range of coals delivered in different localities under varying conditions. Twenty-three coals—low-grade anthracite, low- and high-volatile bituminous, and semi-bituminous coals—are represented, mined in ten States—Pennsylvania, Maryland, West Virginia, Ohio, Illinois, Indiana, Kentucky, Tennessee, Alabama, and Kansas.

Coal from Pennsylvania, Kentucky, and Tennessee competes in Louisville; from West Virgiina, Maryland, and Pennsylvania in Detroit; from West Virginia, Ohio and Pennsylvania in Toledo, etc., and falls within the specification limits especially fixed in each case.

While a rating in comparative British thermal unit value enables the making of an award to the best economic advantage, in certain instances other factors than the mere theoretical heating value may have considerable weight. This is especially so where any uncertainty exists as to the suitability or adaptability of an untried coal to the actual plant conditions of furnaces, grates, draft, labor of handling coal and ash, storage facilities, etc.

In some plants, where boiler capacity is limited, grate area small, or draft weak, only the best grades of coal can be burned, and it is therefore desirable to take bids on a general specification, so that the result of making radical changes in the boiler plant to take advantage of the coal which will give the best economic return may be determined.

In some places it has been found desirable to test the market in more than one class of coal. In Chicago, for instance, two specifications were issued, one applying to Illinois or Indiana washed nut coal and the other to West Virginia or Maryland semibituminous coal. This action was taken in order to determine whether a change from coals high in moisture and ash and relatively low in British thermal unit value as well as price, to high-grade coals at the higher price commanded in that locality, would be justified.

It goes without saying that the relative facilities, competency, and responsibility of the competing firms must also be recognized in making awards.

Compilation of Load Factors

E. W. LLOYD

With the rapid adoption of differential rates by central station companies, based on consumers' load factors, it is absolutely necessary that the commercial man have same practical data on the load factor of different industries before he can arrive not only at the rate per kilowatt-hour which the consumer will earn, but at the quantity of electricity he will consume.

It is not many years since most manufacturers thought the actual connected motor or lamp load was the real maximum load on his plant, but we know to-day that this is not true in a great majority of cases, and that the true maximum rarely exceeds 75 per cent. of the connected load.*

In arriving at the load factor of a given plant, already electrically-driven, it becomes necessary to install maximum measuring instruments as well as wattmeters. On direct-current circuits, correct reading instruments are available, the instrument being of a type both efficient and cheap; but for measuring the maximum on alternating-current circuits we have not been so fortunate. So far as the writer knows, there is not available to-day a cheap and efficient instrument for this service. There are some expensive printing meters on the market, but no central station company could afford this expensive instrument for any but large users, and for this reason very few companies have been able to secure data on load factors that are at all reliable.

For the man in the commercial department it is necessary to have some information of this kind, and it is fortunate that some of the larger companies have been collecting information on load factors for some years. This information the writer has endeavored to collect on the ordinary classes of business we are familiar with, for the use of commercial men selling electrical energy for power and lighting purposes. There are quite a number of industries outside the list mentioned in this article, but unfortunately no reliable information is available at this time.

As before stated, a maximum measuring instrument to be used on alternating current circuits not being available, the Commonwealth Edison Company, of Chicago, serving a territory with alternating-current circuits in which there were thousands of manufacturers, found it necessary to establish a schedule of maximum percentages, based on the average maximum of several thousand customers who had been using direct current for years. The following table is one that has been adopted for alternating-current power business exclusively:

Installations under 10 h.p. where only one motor is used	85 per cent. of connected motor load
Installations under 10 h.p. where more than one motor is used	75 per cent. of connected motor load
Installations from 10 h.p. to 50 h.p., both inclusive, irrespective of the number of motors	65 per cent. of connected motor load
Installations over 50 h.p. irrespective of the number of motors used.	55 per cent. of connected motor load

The above table does not apply to customers having lighting service as well as power. It is probably at least 10 per cent. low should lighting be connected with the power.

While the above table may seem low to some for installations above 50 h.p., we find from actual experience that it is often too high and that we are obliged to install instruments to register the proper maximum. Of course, where a large proportion of the installation consists of blowers or ice machines, or other machinery in this class, the percentages may be low, but generally speaking, they are not. However, in order to protect the power company from demands greatly exceeding these percentages, a clause can be incorporated in contracts providing for a test of the maximum at any time.

It may be interesting to know that we have found that out of 3900 consumers of power, having installations aggregating 35,000 h.p., the average maximum was 53.5 per cent. of the connected motor load and that this was subdivided as follows:

An analysis of the load factors of over 50,000 consumers of electric light in many different classes should be interesting. The figures are taken from actual reading of watt and maximum meters, and are as follows:

		Maximum
Installations of 1 5-h.p.	2900 customers,	75.4 per cent. of connected motor load
Installations of 6 10-h.p.	456 customers,	64.5 per cent. of connected motor load
Installations of 11 20-h.p.	237 customers,	64.7 per cent. of connected motor load
Installations over 20-h.p.	307 customers,	42.9 per cent. of connected motor load

The above percentages are not based on momentary peaks, but on peaks as registered by Wright demand meters.

For commercial reasons, it would not be advisable for a selling company having steam-generating apparatus to establish any system of rates based on momentary peaks. Any ordinary steam plant is capable of taking care of ordinary overloads for at least 15 minutes without undue strain on the apparatus. Therefore, it is unwise to use momentary peaks as the basis of determining a system of rates.

Considering an isolated plant, generating power for a given industry, this plant must be of such capacity that it can take care of the highest demand to be made on it. This high maximum condition may be during only one week of the year. Fixed charges in such a case are, therefore, greater in proportion to the units output than where the maximum is about the same from day to day. In such a plant the operating charges are also higher per unit generated, because the load factor is generally poor, the generating apparatus being less efficient under these conditions. It is scarcely necessary to point out that fixed charges continue as long as the plant does, and that no matter what the load factor of a plant may be these fixed charges are always the same. Generally speaking, they consist of interest, depreciation, taxes, insurance and rental value of space. After fixed charges are taken care of it becomes necessary to pay for the operation of the plant. These operating charges are labor, fuel, water, supplies, repairs, removal of ashes, lamps and the like.

In making up a system of rates based on the load factors of possible customers, it therefore seems reasonable to have what is known as primary and secondary charges, the primary charges to consist of a price per kilowatt-year of demand, and a secondary charge per kilowatt-hour. This method of charging has already been adopted by some of the larger central station companies and is steadily growing in favor. In the use of such systems of charging it is necessary to have information as to the maximum demand as well as the kilowatt-hours' consumption of a possible consumer.

We have succeeded in collecting a large amount of information relative to load factors of different kinds of manufacturing business. These load factors were taken on plants that operated normally during a 54-hour week. Such business as department stores, refrigerating plants and hotels continue longer hours, and the load factors are based upon their actual running conditions. The load factors for any business that normally runs only an approximate 54-hour week would not apply should any industry in this class run two shifts of men

*N. E. L. A., 1909

LOAD FACTORS OF SMALL AND MEDIUM LIGHTING CUSTOMERS

Kind of Business	Number of Custom-ers	50-Watt Equiva-lent	Monthly Kwh.	Total Kw. Max.	Load Factor	Ratio of Max. to Connected Load
Amusements	245	32,592	100,265	904	15.2	56.3
Banks	100	9,102	35,334	304	16.1	66.8
Barns	542	7,068	17,872	242	10.2	68.5
Caths	17	380	1,086	12	11.8	66.9
Bontractors	53	3,327	16,489	99	22.9	59.8
Breweries	36	3,314	7,085	74	13.2	44.8
Building owners	147	8,324	39,120	209	26.5	50.3
Buildings (public)	18	3,152	6,750	53	17.6	33.6
Churches	15	3,301	8,274	92	12.4	56.0
Clubs	65	12,071	16,988	244	9.6	28.8
Commission houses	238	4,996	20,164	172	16.2	68.9
Express Co.'s (small)	89	4,073	14,250	90	21.9	44.3
Flats	24,177	328,939	443,530	8,927	6.9	54.1
Foundries and rolling mills	104	6,679	10,939	184	8.2	55.1
Halls, apartment buildings	2,473	9,915	62,863	616	14.2	90.0
Halls (public)	193	14,136	24,317	486	6.9	68.6
Hotels	103	9,072	22,443	127	24.4	28.0
Houses	5,151	189,616	229,753	4,076	7.8	43.0
Loan firms	35	1,033	3,113	32	13.3	62.8
Monuments	4	323	1,215	100	16.4	63.5
Offices (business)	3,704	77,230	163,657	2,482	9.2	64.2
Offices (professional)	1,563	25,529	39,736	817	6.7	64.0
Photographers	159	4,393	6,483	170	5.3	77.6
Pool and billiards	97	2,711	11,007	87	17.4	64.5
Printers and engravers	381	14,680	45,872	433	14.7	59.0
Publishers	94	5,110	9,104	155	8.1	60.8
Railroad business	105	8,510	41,504	320	17.9	75.0
Restaurants	550	20,846	92,308	547	23.4	52.3
Saloons	2,060	50,002	234,711	157	20.8	62.6
Shops (bakery)	251	3,746	12,684	133	13.1	71.3
Shops (barber)	443	4,883	14,214	172	11.5	70.4
Shops (bicycle and electrical)	62	761	1,309	23	7.7	61.9
Shops (blacksmith)	109	1,840	2,190	611	5.0	66.5
Schools	78	5,515	7,639	148	7.2	52.9
Shops (carpenter)	58	970	1,135	27	5.8	55.5
Second-hand dealers	47	1,646	2,866	36	11.0	44.0
Shops (machine)	125	5,715	6,654	106	8.7	37.2
Shops (paint)	107	4,222	8,739	105	12.1	49.8
Shops (tailor)	552	16,796	30,462	498	8.4	59.3
Social settlements	21	3,037	6,140	79	10.7	52.5
Stables (livery)	103	2,612	10,862	68	22.2	52.3
Stores (art)	91	2,203	5,497	75	10.2	68.5
Stores (book and stationery)	81	2,615	7,052	87	11.7	66.4
Stores (cigar)	226	5.562	21,924	180	16.8	64.7
Stores (small)	49	3.069	6,293	127	6.8	83.1
Stores (dry goods)	367	11,835	26,774	453	8.2	76.5
Stores (drug)	833	17,018	92,809	671	19.3	78.8
Florists	129	3,295	12,205	1,184	10.1	71.8
Stores (furniture)	225	18,741	28,105	654	6.0	69.7
Stores (gentlemen's furnishing)	157	5,270	15,322	18[illegible]	11.6	69.3
Stores (grocery)	434	6,576	17,985	240	10.3	73.0
Stores (hardware)	159	7,925	12,182	158	10.6	40.0
Stores (hat)	41	1,662	5,371	54	14.5	65.0
Stores (house furniture)	8	279	409	7	7.8	52.0
Stores (jewelry)	316	8,813	30,424	283	15.0	64.1
Stores (millinery and dressmaking)	280	9,982	31,793	348	12.7	69.7
Stores (music)	41	1,677	3,664	40	12.4	48.8
Stores (piano)	33	4,260	10,241	108	13.0	51.1
Stores (shoe)	307	6,499	15,172	216	9.8	66.5
Stores (cleaners and dyers)	133	3,373	5,409	94	8.0	56.3
Stores (clothing)	204	14,293	22,096	378	6.6	52.9
Stores (confectionery)	322	6,422	17,193	197	12.5	61.5
Stores (coffee)	127	2,115	5,169	78	9.1	74.5
Supply houses	372	18,815	49,668	556	12.4	58.8
Shops (plumbing)	39	734	1,090	16	8.9	46.0
Small hotels and rooming houses	66	2,022	12,817	684	26.0	67.4
Stores (bird)	2	89	477	3	19.0	78.8
Stores (crockery)	19	1,170	1,590	30	7.2	52.4
Shops (harness)	5	54	98	2	7.5	67.8
Laundries	42	651	1,647	22	10.3	67.5
Meat markets	325	5,089	12,346	187	9.1	73.5
Undertakers	103	2,381	4,618	69	9.3	57.9
Telephone companies	15	363	2,592	12	29.0	67.0
Theatres	18	8,264	24,994	200	17.2	49.0
Tunnel companies	6	584	2,284	12	27.0	40.5
Warehouses	109	6,686	12,020	138	12.0	41.4
Wholesale houses	201	17,113	55,740	401	19.4	46.6
Wines and liquors	45	1,919	7,214	63	16.0	65.5
Manufacturers	1,061	52,129	94,842	1,397	9.5	53.5
Auto. and garages	204	7,596	20,524	228	12.4	60.5
Wrecking companies	2	139	917	5	21.2	76.8
Hospitals	34	3,290	6,248	69	12.5	42.3
Milk depots	52	1,192	4,050	37	14.9	63.0
Hay, grain, feed and coal	112	2,081	3,888	81	6.7	77.6

or run a night shift occasionally. Any increase in the hours' use of the current in this way would tend to better their load factor.

The figures include both power and light, and are on the larger class of customers, and in the majority of cases mentioned the power predominates to a large extent, the light having a comparatively small effect on the load factor. These figures are based on the yearly load factor. Some months the load factors are better than in others, but the figures given are an average.

The load factors in this table may vary somewhat in different parts of the country, due to the difference in the time of sunset. This, however, would not seriously affect the load factor of the power end of the business, but would apply largely to the lighting. However, adjustment of this difference can be made without much trouble by a little study of the local conditions.

Tests taken by curve-drawing instruments or by the reading of the wattmeters in a given plant during 5-minute intervals all day indicate a wide variation in the load conditions on almost all manufacturing plants. Maximum load conditions in factories in Chicago seem to be between 4.30 and 5.00 in the evening, regardless of the time of the year. The maximum load conditions in these industrial plants do not, therefore, come at the time of the peak conditions of the central station. This applies only to plants using power and very little light. There is a point of maximum in these plants at the time of the central station peak, but generally speaking, it is not highest maximum of the customer. This falling off of the factory load before the time of the central station peak is one of the reasons why the central station company is enabled to carry much more business than it would reasonably seem able to. This difference in the time of the maximum of different classes of business makes what is known as the diversity factor.

Large central station plants are usually capable of taking care of motor and lighting customers having a combined connected load of from two to three times greater than the maximum generating capacity of such a plant. This is demonstrated by the fact that the load factor of large central stations is from 30 to 40 per cent., while in the average industrial plant the load factor rarely exceeds 25 per cent.

In referring to the load-factor table heretofore mentioned, you will notice considerable variation in the figures. If a central station company were to secure all of the business in a given city, the diversity factor of all of these customers would be such that the load factor on the station would probably be in the neighborhood of 50 per cent. As in some of the best central stations the load at present is in the neighborhood of 40 per cent., some may question the possibility of raising this condition to 50 per cent.; but if we consider that the time of travel on surface lines and elevated trains is necessarily after the time of the peak, and that the time of travel on suburban steam trains is fully a half hour later; further, that in large centers there is a large amount of summer business, such as amusement parks and large refrigerating plants, and that the time of house-lighting peak is later in the evening, we can reasonably hope that in the future our load factor will be considerably better as we secure more business.

Even with so good a load factor as 50 per cent., we still have a long way to go before we obtain the ideal in central station conditions. It seems necessary, therefore, that central station companies must look to the improvement of their load factors by encouraging the making of by-products from electrical energy; prod-

Kind of Business	Load Factor 8760-Hour Year, Per Cent.	Ratio of Actual Max. to Connected Load, Per Cent.	Hours Used per Day of Max. 365-Day Year
Butter and creamery	20	60	4.8
Breweries	45	60	10.8
Brass and iron beds	20	60	4.8
Biscuit manufacturers	35	55	8.4
Boots and shoes	25	65	6.0
Brass manufacturing	28	50	6.7
Boiler shops	18	45	4.3
Can manufacturers	30	70	7.2
Candy manufacturers	18	45	4.3
Clothing manufacturing	15	55	3.6
Clubs (large)	40	85	9.6
Department stores (large)	30	55	7.2
Electrical manufacturing	25	55	5.5
Express companies	40	60	9.6
Electro-plating	25	75	6.0
Engraving and printing	19	60	4.6
Fertilizer manufacturing	75	40	18.0
Furniture manufacturing	28	65	6.7
Foundries	15	75	3.6
Forge shops	30	49	7.2
Grain elevators	10	75	2.4
Glove manufacturing	25	55	6.0
Grocers (wholesale)	20	55	4.8
Hotels (small)	35	50	8.4
Hotels (large)	50	40	12.0
Ice-cream manufacturing (large)	45	75	10.8
Jewelry manufacturing	18	50	4.3
Laundries	25	70	6.0
Machine shops	26	55	6.2
Newspapers	20	75	4.8
Packing houses	30	75	7.2
Paint, lead and ink manufacturers	23	45	5.5
Paper-box manufacturers	25	50	6.0
Plumbing and pipe fitting	26	55	6.2
Post offices	50	30	12.0
Power buildings	27	40	6.5
Refrigeration	50	90	12.0
Railroad depots	50	50	12.0
Pneumatic tube	50	90	12.0
Soap manufacturers	25	60	6.0
Seed cleaners	25	55	6.0
Screw manufacturers	30	75	7.2
Spice mills	20	55	4.8
Saw manufacturers	30	55	7.2
Structural steel	22	40	5.3
Sheet-metal manufacturers	18	70	4.3
Stone cutters	17	55	4.2
Twine mills	30	60	7.2
Theatres	16	60	3.8
Large restaurants	50	60	12.0
Small restaurants	30	70	7.2
Woolen mills	27	80	6.5
Wood-working	28	65	6.7
Textile mills	20	65	4.8

ucts that could be used in large quantities, such as ice and nitrates.

There has been some discussion as to the advisability of selling power off the peak of the central station. This would be a dangerous thing in a large center where it is nearly impossible to control the situation. If a number of contracts were made with customers off the peak, and they, for some reason, used the energy on the peak, I am afraid the central station would have considerable trouble in adjusting the matter. In a small town it is very easy to watch the few large customers and see that they keep to their agreements. In any small town, where the amount of power used is small, it might be a reasonable propostion to sell the power in this way to advantage.

Any business a central station can get during the summer months should not be strictly considered as off-peak business in the ordinary meaning of the term, and as the time of this load is easily controlled, this business should be sought after by all central station commercial men.

I should like to point out the great value of the collecting of load factors on different industries by different companies. It would help the commercial department of the different companies immeasurably if such information were available. No true analysis can be made of current consumption by different customers unless this information is at hand, and if we expect our commercial men to handle larger customers intelligently we must place in their hand the necessary information. The selling of electricity in larger quantities is becoming common, and we find it becomes more necessary every day to have the men in the commercial department properly educated on every point in connection with the obtaining of this larger business. How can you expect your representative to talk intelligently to a man about the purchase of electricity if he cannot tell the customer how much the net cost will be to him? In every other commercial line it is absolutely necessary that the representative have these figures; in fact, they are the first thing he learns. In our business it seem to be, up to date, the very last thing that is learned. Even in larger companies, up to within a very few years, the officers of the company have handled the larger propositions. Now, when electricity is being sold at rates that can compete in a great many cases with any form of power that can be generated from a private plant, it is necessary on account of the large field that more men be able to discuss the larger propositions intelligently.

The information given in these tables is not perfect, but is accurate enough so that it should be of great help to the men in the field.

In closing, I will say that there seems to be some difference of opinion as to the exact meaning of the word "load factor." The American Institute of Electrical Engineers' Standardization Rules say the "load factor" is the "ratio of the average load to the maximum load." This term ought to be more closely defined. The term "maximum load factor" might mean the ration of average kilowatts to maximum kilowatts. The term "capacity load factor" might mean the ratio of average load to capacity of the plant, the connected load factor the ratio of average kilowatts delivered to connected kilowatts. It might also be stated that there is some misunderstanding as to the term "maximum demand"; whether the load factor is figured on momentary, 1-minute, 15-minute or 1-hour peaks; whether the absolute or momentary maximum be used or the average maximum be used in determining the load factor. By applying these different conditions you might have many different kinds of load factors, such as momentary or absolute maximum load factor, average maximum load factor, to be made up of the average of momentary peak loads, 5-minute load factors, half-hour maximum load factors.

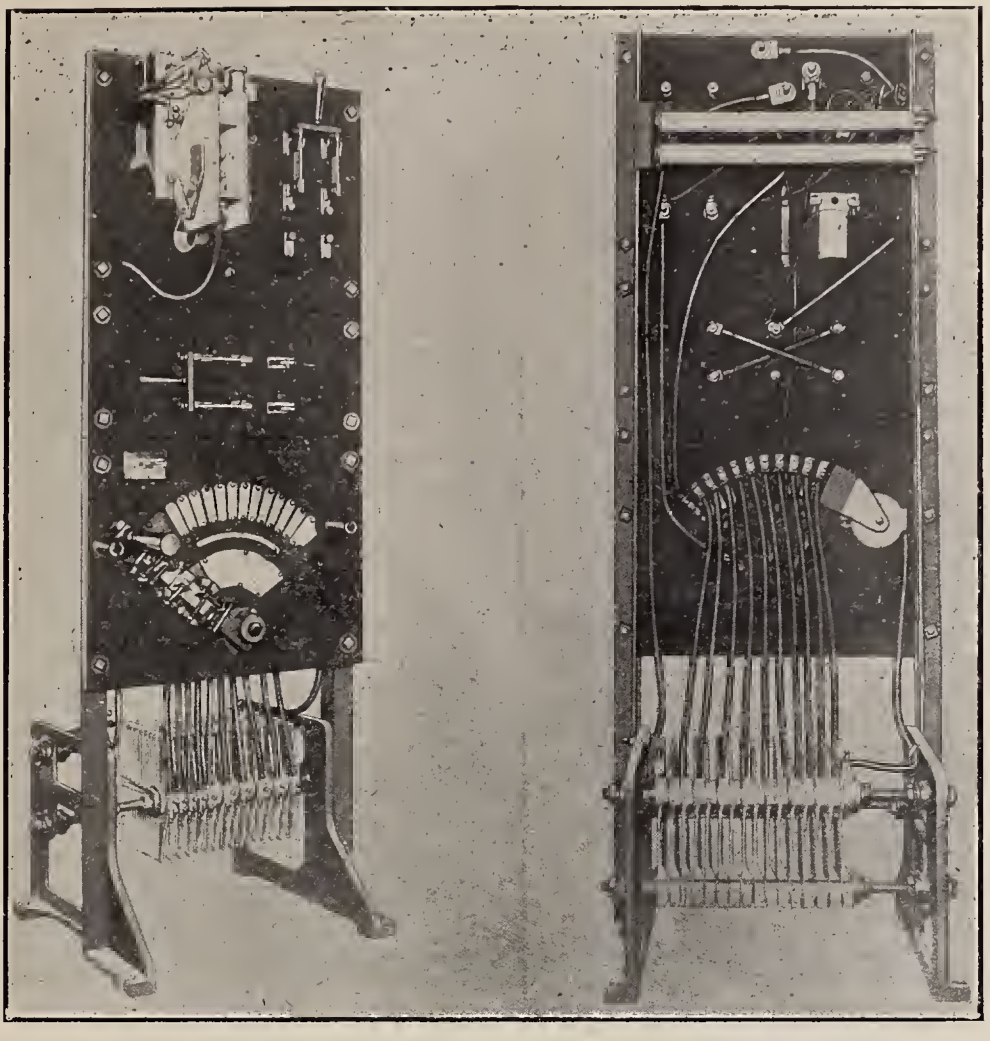
Of course, it is understood that all of these load factors would be on the yearly basis, as the monthly load factor might vary considerably from the yearly load factor; for instance, as in the case of the refrigerating plant, where in the North for seven months in the year the plant runs at a load factor of, say, 75 per cent., whereas in the winter time the load factor probably does not exceed 30 per cent.

New Line of Motor Starters

Recognizing that there is a demand for a motor starter of rugged construction, the Electric Controller and Mfg. Co., of Cleveland, Ohio, has developed and placed on the market a new line of starters which are essentially of mill-type design.

The desire to meet exceptionally severe operating conditions has led to the use of some features not found in any existing motor starter.

The starters are furnished in several forms, beginning with a very simple form and elaborated on to embrace such features as no-voltage release, overload protection for running, and separate and different overload protection for accelerating. In explanation of the last-named fea-



MILL-TYPE MOTOR STARTERS—ELECTRIC CONTROLLER & MFG. CO.

coil is used for securing overload proture, this design allows more current to flow through the motor during starting than during running. If a motor be connected to a load having large inertia—such as a hot saw or a press with a heavy fly-wheel—the mere accelerating of the load demands a very considerable expenditure of work. Since this starting is relatively infrequent, the motor will not be injured by employing a starting current in excess of the running current. Yet the starting time will be materially reduced. There are, in fact, numerous instances where it is desirable to allow an accelerating current larger than the running current.

It is claimed by the Electric Controller & Supply Co. that no-voltage protection, which is secured by a spring-return arm, is open to the following serious objections: First, the spring is likely to be either broken or weakened so that upon voltage failure the arm does not return to the off position. Second, the contacts may become so roughened that the spring is not powerful enough to move the arm. Third, an ignorant operator may block the arm in the off position, so that it is impossible for the spring to properly perform its function.

If, through any cause, the arm is not returned to the off position upon voltage failure, the motor will necessarily be subjected to a damaging overload upon the return of voltage.

In the mill-type motor starters, the danger of a broken or weakened arm spring is absent, because no such spring is used. The no-voltage protection is secured entirely by a magnetic switch which opens upon failure of voltage. This same magnetic switch in connection with an overload tection. Since the overload feature must stand the abuse and have the characteristics of a circuit breaker, it should possess the advantages and arc-breaking ability of a circuit-breaker.

The following valuable features summarize the operation of this type of motor starter:

First—The magnetic switch can be closed only by bringing the arm to the off position, preventing injurious overloads to the motor upon the return of voltage after voltage failure.

Second—The magnetic switch can be held closed to the arm on any accelerating step only by holding in a push button. This prevents leaving any of the starting resistance permanently in circuit, and thereby burning out this resistance.

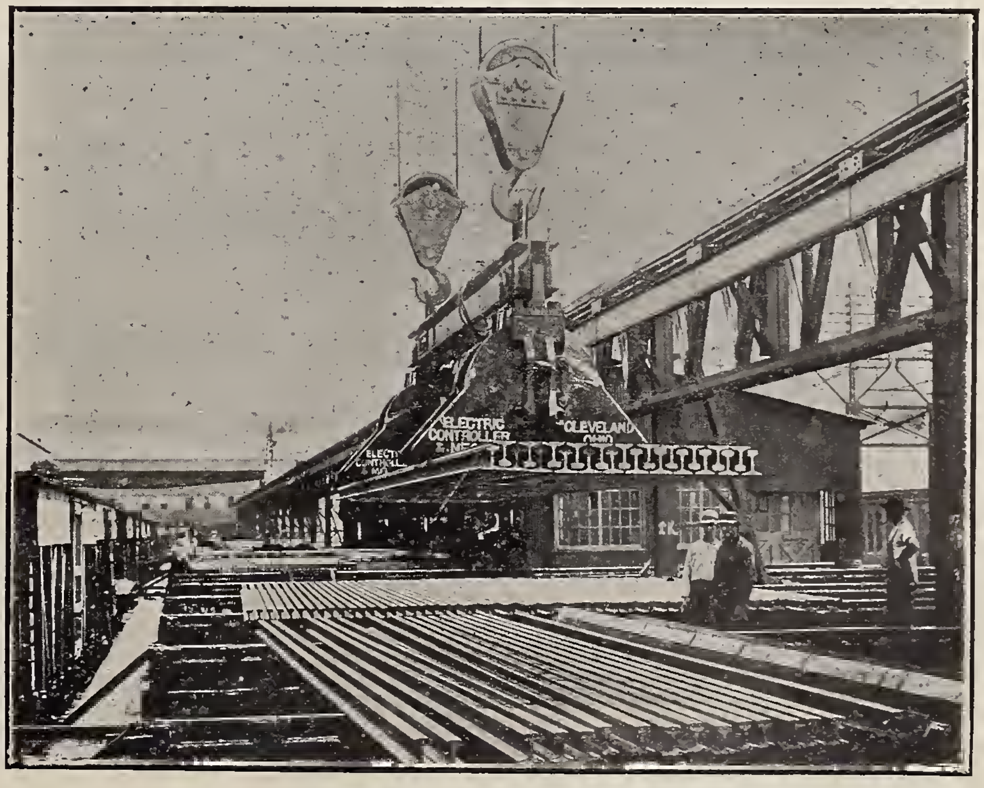
Third—The magnetic switch will maintain itself closed only when the arm is at the full on position.

The resistance, fingers, contacts, etc., used in the mill-type motor starters are of the same design and kind of material that the Electric Controller and Mfg. Co. use in controllers for heavy service, and is well able to stand the same abuse and severe service which the most ruggedly constructed mill-type motor can be expected to encounter.

Rail Handling Magnets at Gary

During the past few years the saving that can be accomplished by the use of lifting magnets has been generally recognized and many new applications of magnets have been made.

Such an application requiring a new design of magnet is the handling of the entire output at the immense rail-mill of the United States Steel Cor-



RAIL LIFTING MAGNET—ELECTRIC CONTROLLER & MFG. CO.

poration's plant at Gary, Ind. This mill is of the most modern design in every respect, and electric power has been used throughout, even to the driving of the rolls by 6000-h.p. motors. The handling of the finished rail by electric power through the use of lifting magnets was, therefore, a logical conclusion, providing a successful magnet could be made. The handling of the rail output by means of magnets was particularly desirable from the following considerations:

1st—Sufficient labor alone could be dispensed with to make the application commercially attractive.

2d—A large saving in time of handling would be effected.

3d—Very much less timber spacing material was necessary in loading.

4th—There being no possibility of bending the rail when loading by magnets, loss on this score would be eliminated.

While it is desirable from the standpoint of the rail-mills and railroads to ship rails in locked sections, yet this is an arrangement of rails which is particularly difficult to handle with a magnet.

The difficulty arises from the fact that the top layer of the rails practically short-circuits the magnetic field and none but a very powerful and carefully-designed magnet would have sufficient strength to penetrate the top layer of rails and lift the bottom layer.

The magnets which were furnished by the Electric Controller & Mfg. Co. have been very successful and have lifted not only locked sections of 33-ft. rails, but have also successfully lifted locked sections of 60-ft. rails with an aggregate load of 15 tons.

Book Review

"Alternating-Current Machines" — Samuel Sheldon, Hobart Mason and Eric Hausman. 353 pages, 263 illustrations. Published by D. Van Nostrand Company. Price $2.50.

This book is a companion volume to authors' text book on "Direct Current Machines. The favor with which this book has met is evidenced by the fact that this is the seventh edition. The book is intended primarily for use in technical schools and for that reason numerous problems are interspersed through the different chapters.

"Dictionary of Chemical and Metallurgical Material, 1909; first edition, price 50 cents. Published by Electro-chemical and Metallurgical Industry, New York.

"The object is not to give a complete directory of the trade, since representation in this dictionary is limited to the advertisers," and therefore

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CONTENTS

The Hard-Drawn Copper Specifications

At first blush it would seem that standard specifications issued by a representative body would be an unmixed blessing to consumers and manufacturers alike. This is, unfortunately, an illusion; the standard specifications usually turn out to be worthless and the world continues to specify as gayly and differently as ever.

We all know the joke specifications issued by that society of the jocular name of Rubber Covered Wire Engineers' Association. Mr. W. A. Del Mar in his "Electric Power Conductors" very justly remarks of it: "The number of compounds which it is intended to cover is so great that it will pass practically anything."

The latest standard specifications are those issued by no less an institution than the American Society for Testing Materials and relate to hard-drawn copper wire.

We propose to test the usefulness of these specifications by putting ourselves in the place of an engineer about to purchase some wire for a transmission line and then consider the effectiveness of the specifications in securing the quality of material desired for this purpose.

The size of cable, spacing of poles and factors of safety having been settled, we wish to determine the height of poles and mechanical qualities of wire to the end that in the hottest weather the wire may not sag too close to the ground and in the coldest weather the tension in the wire will not be so great as to permanently stretch it. We consult our copper-wire authorities and find that for the size we intend to use the wire begins to stretch permanently when it is subjected to a stress of, say, 35,000 lb. per square inch. Hence we must adjust our sag so that at the lowest temperature the tension will not exceed 35,000 lb. per square inch, or whatever less we may choose for safety, and we must adjust our pole heights so that on the hottest summer day the wire will not droop to within an undesirable distance of the ground. In order to make these calculations we require the elongation at the elastic limit, a figure which, divided into the elastic limit, gives the modulus of elasticity. Remembering our proposed factor of safety, we must know the ultimate strength in order to determine whether our winter tension is not too high to give the desired factor.

We then specify the pitch in order that we may have sufficient twist to ensure the integrity of the cable, and yet avoid an excessive obliquity of the wires, which would reduce the tensile strength.

If the cable is large, we are confronted with the fact that the cable manufacturers have not the equipment necessary for testing it. We are, therefore, obliged to rely upon the tests of individual wires and calculate therefrom the strength of the cable. Hence we require data on the relation between wire strength and cable strength. The strength of a cable is less than the combined strength of its individual wires, due to the following causes: The obliquity of the strands prevents the molecular forces acting in the direction of the load, an effect which will be considered at greater length below. The effect of stranding is to alter the molecular condition of the wire impairing its strength in most cases. Data on these subjects are required where the manufacturers are unable to make direct tests.

—

If the cable is to be spliced by unstranding the ends, dove-tailing the wires together and wrapping them individually around the unspread part of the cable, we want to be assured that the wires will not break during the process. We accordingly specify that they shall be capable of being wrapped around a mandrel of given diameter without cracking or developing other surface injury.

Briefly, we want the quantities tabulated below in column I. Compare them with the list of quantities enumerated by the American Society for Testing Materials given in column II:

I	II
a Elastic Limit.	——
b Modulus of Elasticity.	——
c Ultimate Strength.	Ultimate Strength.
d Pitch.	Pitch.
e Relation between wire and cable strength.	Relation between wire and cable strength.
f Pliability.	——
g Conductivity.	Conductivity.
——	Elongation at break.

Let us now consider the items of the new specifications individually, referring to them by the letter in the first column:

(a) The elastic limit test is omitted because "the only way in which the elastic limit of hard wire may be determined is by the actual plotting of the elastic curve from extensometer readings." Then a few unimportant errors are cited. The Committee then generously suggests that if the designing engineer wants to know the elastic limit, special tests may be made. *Of course,* the designing engineer wants to know the elastic limit; there is no "if" to be considered. Then why don't they put the elastic limit in the specifications instead of leaving the engineer to get what he may happen to get? A perusal of the personnel of the Committee suggests the answer. There are ten members, seven of whom represent manufacturers of wire and three of whom, presumably, represent consumers. Specifications prepared by manufacturers are always open to the suspicion that they are designed for the economic benefit of the manufacturers only. Any attempt to make a manufacturer toe the mark

without fail will surely be without his approval. With these thoughts in our minds, we feel convinced that the omission of the elastic limit from the specifications under discussion must be of benefit to the wire manufacturers. The benefit arises from two causes; the omission eliminates the necessity of obtaining a high elastic limit; it eliminates the extensometer tests on a large proportion of each order. Are these omissions of benefit to the consumer for whom the specifications are ostensibly prepared?

(b) The modulus of elasticity is not mentioned in the specifications or explanatory notes, a circumstance which indicates the relative influence of manufacturers and consumer in framing the specifications.

(c) The specifications give an imposing table of tensile strengths, which err on the side of being rather low. This table was evidently prepared on the basis of passing everything that is manufactured under the name of hard-drawn copper. Thus, for No. 0 B. & S. the tensile strength is given as 54,500 lb. per square inch, whereas a series of tests on this size wire give a minimum of 57,000 lb. and a maximum of 61,000 lb. per square inch.

(d) A fairly wide range is allowed in the selection of pitch, but why is the pitch specified in terms of the outside diameter rather than the pitch diameter, as is usually done?

(e) The specifications state that "the tensile strength of standard cable shall be at least 90 per cent. of the total strength required of the wires forming the cable."

Using the minimum possible pitch of 10.1 times the pitch diameter, the strength of a cable is reduced about 4 per cent. by the obliquity of the outer wires. Such a short pitch is not allowed by the specifications and in practical cases the loss of strength due to obliquity will be found to be not over 2 per cent. The remainder of the 10 per cent. allowed by the specifications is, therefore, intended to allow for molecular changes during stranding. Like everything else in these specifications, this clause seems intended to help pass everything made in the mills.

(f) The wrap test or pliability test is omitted ostensibly because it is hard to make, but perhaps actually because the manufacturers have suffered unjustly from existing specifications, many of which call for absurd tests of this kind. But "because right principles have been violated is no reason why they should be abandoned," and it is surely reasonable to specify sufficient pliability to enable a splice to be made. Perhaps the Committee will tell us that if the wire passes their specifications it will surely pass a fair wrap test; if that is so, let us have the wrap test by all means.

(g) The Committee tells us to specify the elongation at break. Now what is the elongation at break? When a wire is stretched its length increases at the expense of its cross-section, the reduction in cross-section being uniform through the greater part of the process. At a certain point in the test, however, a spot which is softer than the remainder of the wire stretches abnormally and the cross-section shrinks at that point until the wire breaks. At this moment the elongation is noted. A portion of this elongation occurs in the entire 10-in. length, but the greater part occurs in the 1/10-in. portion, which suffers abnormal stretching. The elongation at break is, therefore, the sum of two elongations, one of which is proportional to the length of the test piece, and the other of which is practically constant. The total elongation is, therefore, an indefinite quantity. This indefinite quantity tells us nothing beyond the fact that the wire is really hard drawn and will not pull out indefinitely like molasses. An engineer who specified this quantity and omitted to specify the elastic limit wrote to his representative at the wire factory in the following terms: "Although not stated in the specifications, the wire should have an elastic limit of 33,000 lb. per square inch. Not having specified this, I do not know that we can compel the manufacturers to furnish it, but kindly advise them of this requirement." We hasten to add that the manufacturers *did not* satisfy this requirement.

The Committee recommends the rejection of Matthiessen's Standard and the substitution therefor of a statement of the lbs. per mile-ohm. Matthiessen's Standard is in the same category as the Fahrenheit scale. It is an extremely artificial standard which has come into universal use. Like Fahrenheit, Matthiessen underestimated nature. Fahrenheit thought that the lowest attainable temperature was that obtained by mixing salt and ice, and he made that temperature the starting point of his scale. Matthiessen thought that perfectly pure copper had a resistance of 9.5916 ohms per mile-foot at 0 degree Cent. and he made that the basis of *his* scale. Both scales have the advantage of being universally understood, and there is no more object in using pounds per mile-ohm than in using the absolute zero of temperature, neither of which carry any idea to the average mind. The excuse that pounds per ohm-mile are actually measured while the position on Matthiessen's scale is derived is not a good one, because someone has to figure back to Matthiessen's scale after all to see what he is getting.

Economy vs. Dirt

For nearly a decade there has been a small and dubious choice of electric illuminants narrowly fixed by the economy of the device in the use of current. The battle has raged fiercely and strong, and big contracts have swung on a paltry difference in current consumption. It has been enough that there was a difference. The broader question of whether the saving in current was overbalanced by other items has seldom been considered except in the case of some freak illuminant whose unknown cost of maintenance and uncertain behavior made its use a risky venture.

Now after all these years of technical controversy we are laughed at by Mr. Eustice, who shows us that the controversial points are insignificant as compared with the deterioration of light caused by the dirty condition of glassware. Carefully he has tested different illuminants after various periods of cleaning, and puts before us these startling facts—startling because the cleaning of glassware is not habitual and only resorted to at times of general house-cleaning or other irregular intervals.

He tells us:

That the beautiful prismatic reflectors show "a gain of 10 per cent." if cleaned once a month;

That the Nernst lamp (and tests are numerous enough to silence doubt of the result) shows an average loss of 4.68 per cent. in seven weeks, or only 3.5 per cent. per month;

That the Holophane B. frosted tungsten shows a deterioration of 28.77 per cent. in 25 weeks, or about 11 per cent. per month;

That the 4-ampere enclosed arc lamp shows about 20 per cent. loss in two weeks;

In the above diversified figures there is much room for reflection. One thing is plain: We must now consider the cost of cleaning in our illumination work if we are to have our high-efficiency in light units. And we must clean our electrical glassware with as much regularity as we clean windows, or were daily wont in olden times to wipe the chimney of oil lamp.

The duty of the central station that guards its interests carefully is also very plain. Electric customers must learn to clean their glassware if they would hold the joy of the first night they turned electricity into the new lighting equipment.

Electric Power

HENRY J. GILLE

In general, the sale of our product is compared with that of other public utilities, such as railway, gas and telephone. There are, however, some important differences that must be taken into consideration in arriving at our cost of production and selling price. The unfortunate condition of our business which requires the manufacture of our product at the time when it is demanded, places it in a class by itself. The street railway takes care of its traffic at times of maximum demand by supplying additional cars and in that way takes care of its "peak" as rapidly as possible. It does not, however, furnish service for instantaneous demand: If a car is loaded the traffic must wait for succeeding cars. The same thing is true of the telephone: If lines are

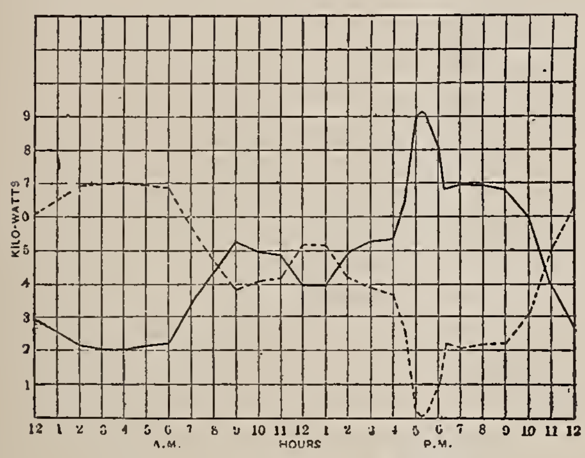


Fig. 1.—STATION LOAD CURVE
Dotted curve, inverted station load curve.
Station load factor, 32.4 per cent.

busy the traffic must wait until service can be furnished. In the gas industry the product is manufactured during 24 hours at practically a uniform rate and stored for the time of heavy demand. The only comparison between the gas and electric industry is in the distributing system, in which the two classes of business are almost identical, except that in the gas industry it is possible to operate with a very widely fluctuating pressure. It is therefore obvious that the sale of electricity occupies a field of its own.*

If it were possible to sell our product so as to keep our generating and distributing systems loaded continuously, we should have reached the ideal condition we are all striving to attain. It is probably safe to assume that station load factors range generally between 25 and 35 per cent., there being exceptions both above and below. It is therefore apparent that if we had 100 per cent. load factor, with the present output we could dispense with between 65 and 75 per cent. of the total capacity investment. We are therefore carrying this investment, which, on a basis of 100 per cent. load factor, is idle, and on a basis of our present load factor our entire investment is idle between 65 and 75 per cent. of the total time. It is evident, therefore, that we have a large capacity available during certain hours of the day, and if it were possible to develop business during this period it would not only reduce the cost per unit of output of our total business, but would greatly increase the earning capacity of our investment.

With new avenues of electrical development constantly being opened up, new problems of the sale of our product as well as the manufacture and distribution present themselves. In the past electric current has been divided into two classes—light and power. Whereas this division seemed at first to be arbitrary, it was soon realized that there was not only a good reason for this division but a basis therefor. One of the earliest arguments presented was that in order to make the electric business a paying one it was necessary to develop a day power load. It was found that in some instances part of it was on at the same time. A large proportion, however, went off at the time the lighting load came on. It was also found that considerable power business developed with intermittent load to such an extent that it had a considerable influence on the total load of the station. In other words, the station demand was smaller in proportion to the total individual demands than was that of commercial lighting, which constituted the central station business at that time. Power load, therefore, established a ratio of cost to serve, different from that of lighting, and as the power business developed this difference apparently increased to a certain point, and the usual condition to-day of a central station load is that a part of the power load overlaps the lighting load. I have no data and do not know that there are any in existence that give the diversity factor for power and light—together or separate—supplied by a central station, covering the period of years during which the largest development took place—which would be interesting and would throw considerable light on this question. It is not, however, the purpose of this paper to analyze power rates or equitable and uniform rates, but to analyze to some extent the effect of various classes of power on station loads, and the advantage of obtaining power load that does not come on the peak, which has been divided into four divisions, as follows:

FIRST—TO WHAT EXTENT DOES THE POWER LOAD OVERLAP THE PEAK?

It is difficult to get reliable information for power and light loads separate, for the reason that both in an average city are furnished from the same system, and in order to show the effect on the peak we have prepared a number of individual load curves of representative classes of business in several cities. These consumers' load curves appear on the same sheet with the station load curves, besides some data that are valuable in considering each class. The consumers' maximum demand and load factor are determined from the yearly records and do not represent the demand shown on the charts. We have also succeeded in getting a station power curve showing a 500-volt system which supplies general power, which is valuable in connection with considering the power that overlaps the peak.

In Fig. 1—Representative Station Load Curve—the dotted line shows the capacity available in this station on the maximum demand day. This curve clearly shows the capacity of the station that is idle during a large part of the 24 hours.

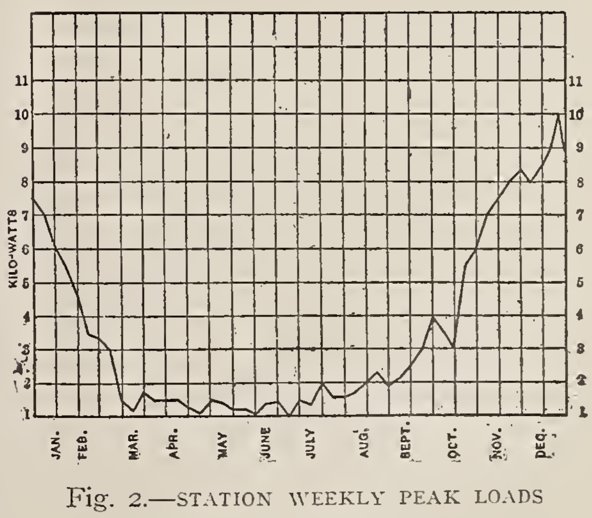


Fig. 2.—STATION WEEKLY PEAK LOADS

Fig. 2—Station Weekly Peaks During the Year—shows the capacity available during the year, assuming the maximum demand day to be the capacity.

*Mr. Gille, in collaboration with a number of others, presented this paper at this year's convention of the N. E. L. A.

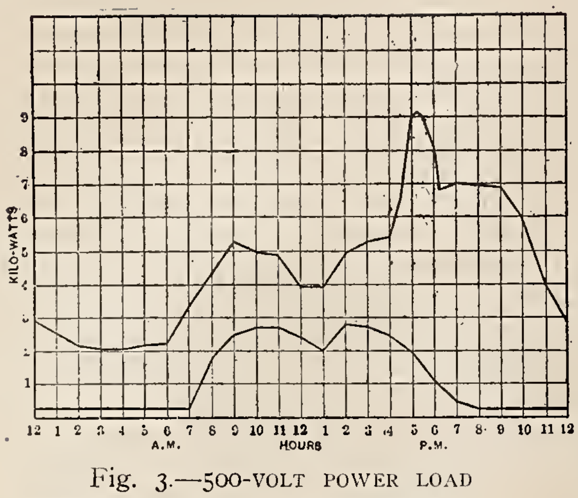


Fig. 3.—500-VOLT POWER LOAD
Multiply by 1,000 to obtain station load.
Multiply by 200 to obtain consumer's load.
Kilowatt-hours per year, 1,966,263.
Connected load, 3,400 kilowatts.
Maximum demand, 972 kilowatts.
Ratio of maximum demand to consumer's load on station peak, 35 per cent.
Load factor, 23 per cent.
Station load factor, 32.4 per cent.

Fig. 3—Total Station Load Curve on the Maximum Demand Day and A 500-Volt Station Power Load Curve Supplying General Power—is the only curve we were able to get showing the power load in connection with the lighting load in a fair-sized city. I might add that the total station load curve includes the power load.

Fig. 4—Composite Power Curve—combines numerous individual tests with a total of 94 motors installed, aggregating 1422 h.p. This curve shows a considerable reduction in the power curve at the time of the lighting peak.

Fig. 5—Wooden-Box Factory—shows peak between 8 and 9 o'clock in the morning. The reason for this is that they operate a large planer, which, by special arrangement, they operate only in the forenoon; in that way reducing the demand at the time of the station peak.

Fig. 6—Car-Accessory Manufactory—consists mostly of foundry and machine work. The extreme peak between 3 and 4.15 covers the power to operate the cupola fan. Whereas the consumer's load factor is extremely low, which is due to the cupola fan, it will be noted that the ratio of consumer's demand to station at the time of the station peak is less than one-half of one per cent.

Fig. 7 shows a feed mill operated during 24 hours in connection with a grain elevator, the elevator being used between 2 and 3.45 in the afternoon. By operating the mill in this manner the consumer's peak goes off before the station peak comes on.

In Fig. 8 the station curve is an unusual one, being extremely large all day and the lighting peak very small. This is an unusual condition and covers a plant in a manufacturing city in the heart of the granite quarries.

Fig. 9 shows a grain terminal elevator. The heavy unloading and elevating grain in elevators usually occurs in the forenoon for the reason that cars are set in during the night.

In Fig. 10—Linseed-Oil Mill—the curve shows part of the mill shut down. A linseed-oil mill is very similar to a flour mill, the load being practically uniform throughout the entire 24 hours. The curve in this case indicates the character of the load and load factor.

Fig. 11—Malt Manufactory—covers a large malt house; the heaviest demand comes before 5 o'clock.

Fig. 12—Marble Works—covers marble works where marble is prepared for building use. Special arrangements have been made with this plant to operate 24 hours and to clean the polishing tables between 5 and 6 in the afternoon in order to reduce the load at the time of the station peak.

In Fig. 13—Paint Manufactory—the curve covers paint grinding and putty mixing. The small peaks represent the putty chasers.

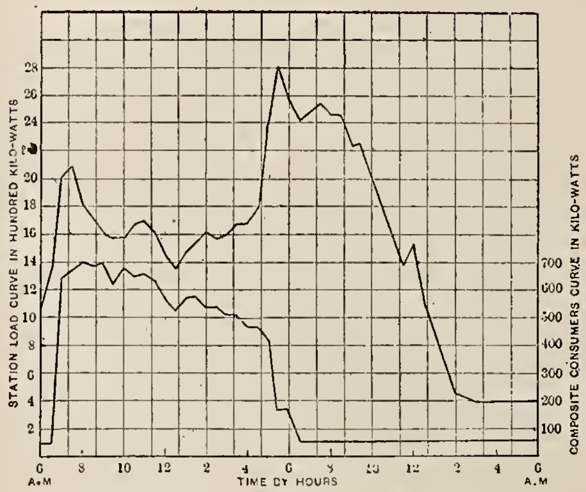


Fig. 4.—COMPOSITE POWER CURVE
Motors installed, 94.
Kilowatts motors installed, 1,422.
Kilowatt-hours consumed per year, 1,902,200.
Maximum yearly demand, 2,854,300.
Consumer's yearly load factor, 66.
Yearly station load factor, 39.3 per cent.

Fig. 14—Printers—covers a typical printing plant, the power being entirely shut off at the time of the station peak.

Fig. 15—Roasting—covers a coffee-roasting plant. The roasting ceases at 5 o'clock. Considerable improvement could be made in the operation of this plant at the time of our peak if roasting ceased at 4.45.

Fig. 16—Shoe Factory—shows a typical shoe factory, which operates from 8 to 5. A large proportion of the machinery is shut down at 4.30.

Fig. 17—Structural-Steel Plant. Arrangements are made with this plant whereby the heavy work is done before 4 o'clock in the afternoon. As this does not inconvenience the shop it is really an advantage, as it gives the men an opportunity to clean up the work of the day.

Fig. 18—Type Foundry—shows a gradual reduction in the consumer's load curve from the time the station peak comes on.

Fig. 19—Wagon Manufactory. All the machinery in this plant that it is possible to operate in the forenoon or early afternoon is so operated. There is, however, a large amount of power on at the time of the peak which covers mostly forges, planers and drills.

Fig. 20—Wood-Working Plant. A large amount of power is on at the time of the peak.

These curves indicate in a general way the class of business that makes up the power peak. We realize that it is not possible to cover all the conditions that exist, as there are not many that are just alike. There is also considerable difference between plants in large and small cities, as well as between cities in the same class, depending altogether on the class of power business developed. It is, however, apparent that a considerable portion of the power business does not come on at the time of the peak. We also feel that considerable improvement could be made by studying the power conditions of the individual consumers, for the reason that it is possible in many cases to operate heavy machinery, which is operated for a short time only each day, in the forenoon or early afternoon without inconveniencing the consumer. Every horse-power that is kept off the peak in that way reduces the station capacity required.

Another suggestion is to get power users to reduce the noon shutdown from 1 hour to 30 minutes, and to shut down one-half hour earlier in the evening. This has been done in a great many cases at the solicitation of the help. If this could be carried out to any considerable extent it would have a material effect on the station peak. This, however, would affect only those stations that have a light and power peak. Some cities, as I have already pointed out, have

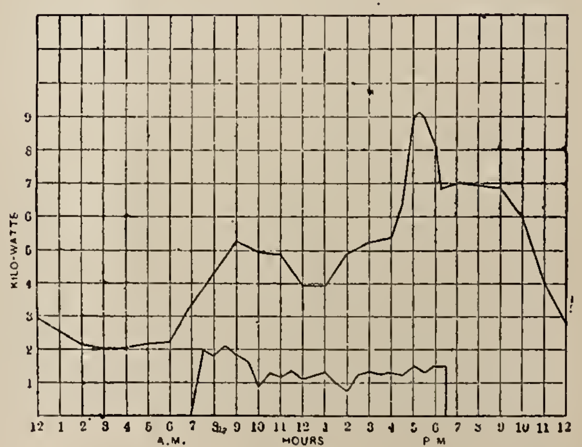


Fig. 5.—BOX FACTORY
Multiply by 1,000 to obtain station load.
Multiply by 48 to obtain consumer's load.
Kilowatt-hours per year, 120,000.
Connected load, 70.4 horse-power.
Maximum demand, 100 kilowatts.
Ratio of maximum demand to consumer's load on station peak, 67.2 per cent.
Load factor, 13.7 per cent.
Station load factor, 32.4 per cent.

only a power peak; however, we think that such are the exceptions.

We have pointed out in a general way that the station demand was smaller in proportion to the total individual demands for power than for light. In order to determine to some

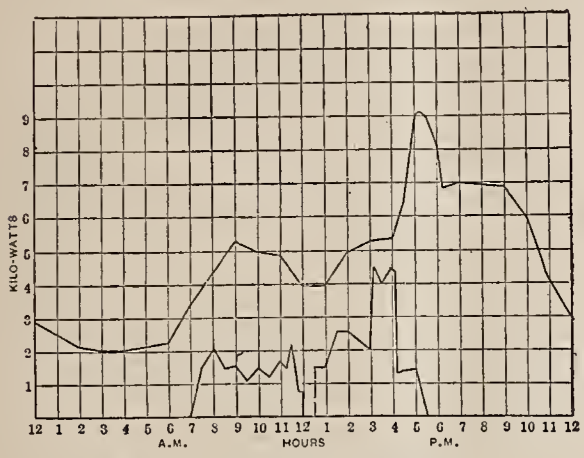


Fig. 6.—CAR MANUFACTURERS

Multiply by 1,000 to obtain station load.
Multiply by 15 to obtain consumer's load.
Kilowatt-hours per year, 48,936.
Connected load, 137.5 horse-power.
Maximum demand, 67.5 kilowatts.
Ratio of maximum demand to consumer's load on station peak, 0.31 per cent.
Load factor, 8.37.
Station load factor, 32.4 per cent.

extent the ratio between the station load and the total individual consumer's demands, we analyzed curves shown on Fig. 3, the consumers on this system, except passenger and freight elevators, being equipped with maximum demand indicators. We found that the total consumers' demands were approximately four times the maximum station demand; in other words, a ratio of 1 to 4. We were unable to check this diversity factor with any other system. However, we feel that it is very important that the diversity factor for power be determined, as well as the diversity factor for lighting and the diversity factor for a combination of light and power, as it is an important item in considering equitable and uniform rates.

SECOND—USE OF CURVE-DRAWING INSTRUMENTS

This, as we understand it, broadly covers maximum demand indicators. In order to insure perfectly fair treatment to all classes of customers, it is necessary to have an instrument for determining the customer's demand. There are three well-known types of instruments on the market, which are used for ascertaining load conditions: *First,* the Wright maximum demand current indicator, which is suitable for use on direct current only. This indicator records approximately 90 per cent. of the demand in four minutes. If the load lasts 10 minutes, approximately 97 per cent. will be recorded. If the load continues for about 40 minutes the full 100 per cent. is registered. This instrument recommends itself to the users for this class of service on account of its simplicity and cheapness. *Second*—a curve-drawing instrument, which has been placed on the market by several companies, shows the demand in true watts, and is made for both direct and alternating current. This instrument is the only recording demand indicator for polyphase circuits indicating instantaneous demand on a continuous load chart. It has been on the market a comparatively short time and has fulfilled the demand for an instrument of this character. The expense of the instrument, however, prohibits its use for small polyphase power, and for this class there is no other satisfactory demand indicator. *Third*—a polyphase kilowatt demand indicator is similar to a curve-drawing instrument except that it indicates only the maximum demand. This instrument has a range of adjustment for time of demand within a reasonable limit. The cost of this instrument also prohibits its general use for small polyphase power. So far as we are able to learn, these three classes of

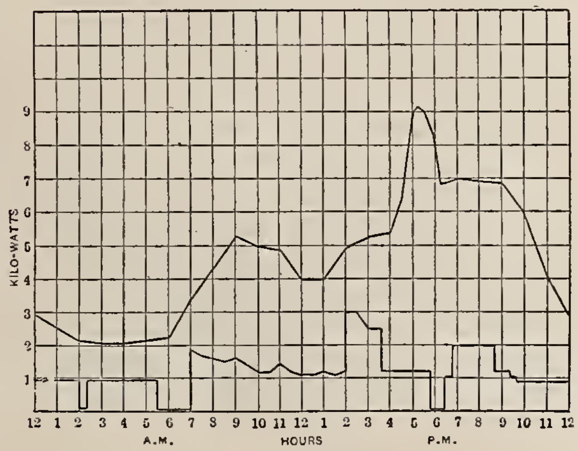


Fig. 7.—FEED MILL

Multiply by 1,000 to obtain station load.
Multiply by 28 to obtain consumer's load.
Kilowatt-hours per year, 306,992.
Connected load, 125 horse-power.
Maximum demand, 75 kilowatts.
Ratio of maximum demand to consumer's load on station peak, 25 per cent.
Load factor, 47 per cent.
Station load factor, 32.4 per cent.

instruments are in general use, the Wright demand indicator being very extensively used on direct-current systems.

There seems to be considerable difference of opinion regarding the length of time for which demand should be taken as a basis of charge. Demands ranging from instantaneous to an average of 30 minutes are in use. In some cases the rated capacities of the motors are used as the basis. It seems to us, therefore, important that some standard should be established, as there seems to be no definite understanding as to what constitutes maximum demand, and if it is considered advisable, we would recommend that this association appoint a committee to report as to the feasibility of establishing a standard.

THIRD—ADVANTAGES OF OBTAINING POWER LOAD OFF THE PEAK

The net earnings of a company are very largely affected by the class of business we push, and how we take care of it after we get it; besides, it determines our costs and ability to furnish service at the lowest cost, and it is evident—as we have already pointed out—that our capacity is idle from 65 to 75 per cent. of the time. We can therefore supply service off the peak without increasing our investment costs; there is no question but what the greatest possible opportunity for increasing the earning capacity of central stations is by increasing the load factor, or in other words, obtaining load off the peak.

FOURTH—USE OF ELECTRICITY IN THE MANUFACTURE OF NITRATES OR OTHER PRODUCTS USING LARGE AMOUNTS OF POWER OFF THE PEAK.

Treating this subject broadly, as the use of power for chemical purposes, which the phrase "or other products" includes, it seems perhaps best not to confine the scope of these remarks principally to nitrates, or even to the fixation of nitrogen, but to allow those subjects to be discussed in their own place.

Certain factors are of prime importance in the consideration of the use of power for chemical manufacture, and of these the following are without doubt of first order:

1. Cost of power.
2. Location with reference to raw materials and market for product.
3. Permanence and continuity of power.
4. Possible output from a given investment.

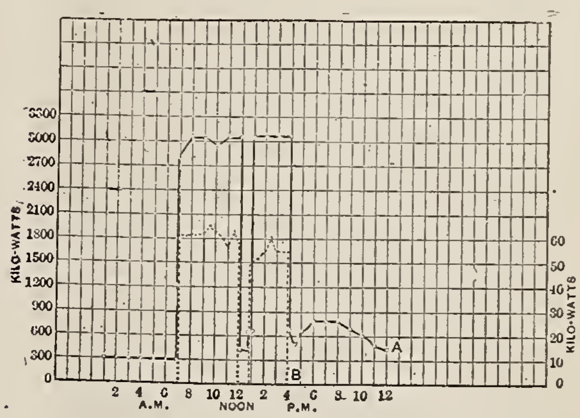


Fig. 8.—A, OUTPUT CURVE MARCH 3, 1909; B, LOAD CURVE, 75-H.P.—GRANITE MANUFACTURING PLANT

Total number motors installed, 198.
Total kilowatts motors installed, 3,379.
Total annual plant output, kilowatt-hours, 8,000,000.
Maximum demand kilowatts, 3,450.
Customer's yearly load factor, 0.52 per cent.
Granite manufacturer's load factor, 0.69 per cent.
Station load factor, 0.23 per cent.
Station power factor, 0.85 per cent.
Tributary population served by one horse-power, 6.2 per cent.

The first factor is naturally the most important, for it is a prime essential that the power used to make chemical products, where the output is a direct function of the electricity used, must be low in cost. Cost ranges in this country from $10 to $25 per kilowatt-year on basis of 354 days of 24 hours. In general, the more important the industry, the larger the amount of power and the lower the price. In Europe, prices range much lower, running down to below $8.00 per kilowatt-year. These prices are on a basis of power delivered to the consumer's switch, all loss and expense of transformation if necessary being borne by him.

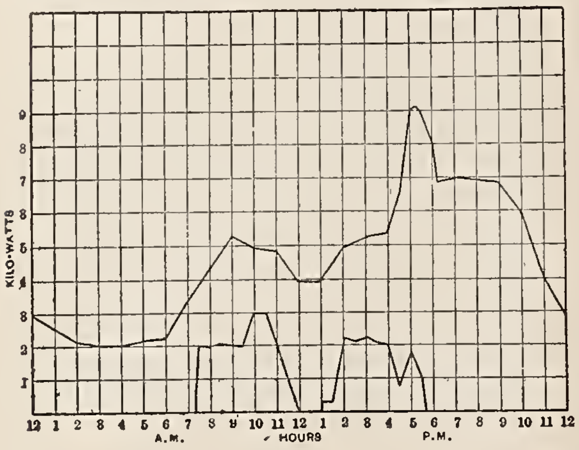


Fig. 9.—GRAIN ELEVATOR
Multiply by 1,000 to obtain station load.
Multiply by 2x4 to obtain consumer's load.
Kilowatt-hours per year, 137,280.
Connected load, 125 horse-power.
Maximum demand, 70 kilowatts.
Ratio of maximum demand to consumer's load on station peak, 48 per cent.
Load factor, 22.4 per cent.
Station load factor, 32.4 per cent.

The factor of location does not require extended explanation, as it is evident that prohibitive transportation rates on either raw material or product might in some circumstances make it impracticable to install a chemical process at a particular place.

The factor of permanence and continuity of power, while not so generally important, nevertheless requires consideration. Certain large electrochemical processes are of such a nature that any interruption, other than for a very few minutes, means serious loss. Therefore the proprietors of such industries must be assured that there is power enough at all times to take care of them, that it will not be interrupted frequently and not at all without notice of perhaps several days. Such power as is indicated in the subject, if it be understood to mean power for, say, 20 hours and no power for 4 hours in each day, could not be considered for such processes.

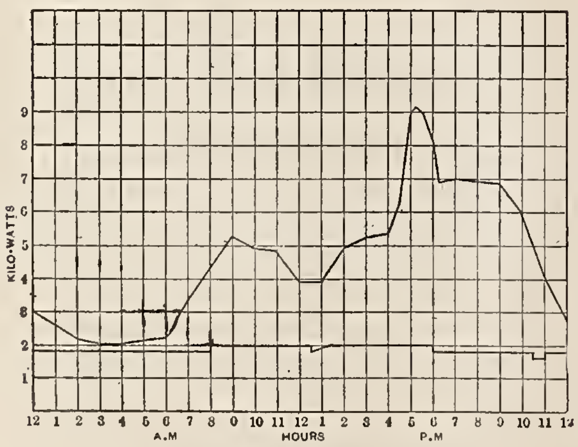


Fig. 10.—LINSEED-OIL MILL
Multiply by 1,000 to obtain station load.
Multiply by 120 to obtain consumer's load.
Kilowatt-hours per year, 1,644,126.
Connected load, 1,000 horse power.
Maximum demand, 262 kilowatts.
Ratio of maximum demand to consumer's load on station peak, 66 per cent.
Load factor, 52 per cent.
Station load factor, 32.4 per cent.

The last factor mentioned is a business consideration pure and simple from the standpoint of the chemical manufacturer. A plant of a certain size, given its designed amount of power 24 hours every day, will yield a certain output per year, from which the profit can be figured as a certain proportionate return on the investment. If the time of operation per day is reduced, in order to make the same amount of product, the size of the plant must be proportionally increased and the investment be proportionally larger. Therefore in choosing between two locations, one giving 24-hour power, the other 20-hour power, other conditions being equal, the manufacturer would expect sufficient reduction in the price of power to surely make up for the 20 per cent. additional investment he must make for a given output.

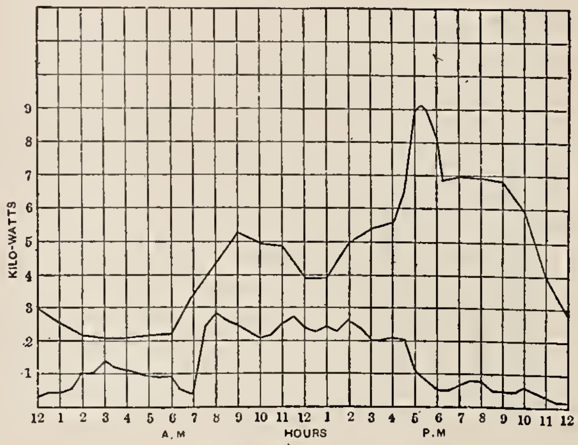


Fig. 11.—MALTING
Multiply by 1,000 to obtain station load.
Multiply by 100 to obtain consumer's load.
Kilowatt-hours per year, 979,120.
Connected load, 648 horse-power.
Maximum demand, 280 kilowatts.
Ratio of maximum demand to consumer's load on station peak, 32 per cent.
Load factor, 40 per cent.
Station load factor,

Considering, for the subject in hand as available, only power supplied for a portion of the day, it will serve the purpose to indicate the character of chemical work that can best withstand such intermittent operation. Such work is principally of the electric furnace order, and, while several furnace processes are now run continuously, they could be operated intermittently without such serious losses as would occur in some of the wet bath electrolytic industries. The following products come under this head: artificial emery, calcium carbide, carborundum, graphite, ferro-silicon and kindred substances—oxides of nitrogen and nitrates, cyanamides. Under the class of processes not of the furnace order which could be adapted to withstand daily interruption are the following: electrolytic refining of copper, recovery of tin from scrap, and the manufacture of oxygen. Electric smelting of ores can undoubtedly be added, but, as this is as yet little developed, it is difficult to say how much continuity of operation counts for.

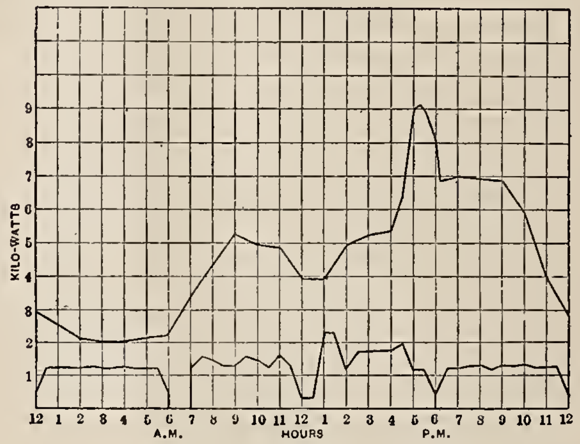


Fig. 12.—MARBLE WORKS
Multiply by 1,000 to obtain station load.
Multiply by 24 to obtain consumer's load.
Kilowatt-hours per year, 101,561.
Connected load, 45 horse-power.
Maximum demand, 55.2 kilowatts.
Ratio of maximum demand to consumer's load on station peak, 64 per cent.
Load factor, 21 per cent.
Station load factor, 32.4 per cent.

The manufacture of artificial emery and carbide of calcium will serve for illustration of the furnace class of products. The first comprises the complete fusion of the mineral bauxite and allowing the same to cool. It is obvious that this operation is naturally intermittent. Calcium carbide is made by heating together, at the temperature of the electric arc, lime and carbon in the form of coke. After the combination is complete, this product is allowed to cool. At the

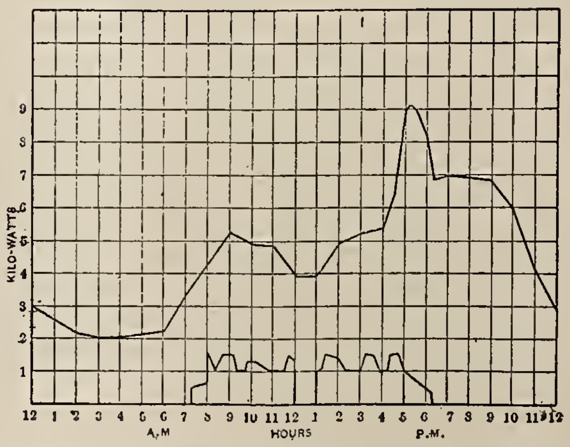


Fig. 13.—PAINT MANUFACTURERS
Multiply by 1,000 to obtain station load.
Multiply by 4.4 to obtain consumer's load.
Kilowatt-hours per year, 13,051.
Connected load, 20 horse-power.
Maximum demand, 7 kilowatts.
Ratio of maximum demand to consumer's load on station peak, 50 per cent.
Load factor, 21.2 per cent.
Station load factor, 32.4 per cent.

present time this operation is carried on continuously in a rotary furnace, but it is by nature of intermittent character.

Since nitrates form a specific part of the subject, it is well to consider the matter of fixation of atmospheric

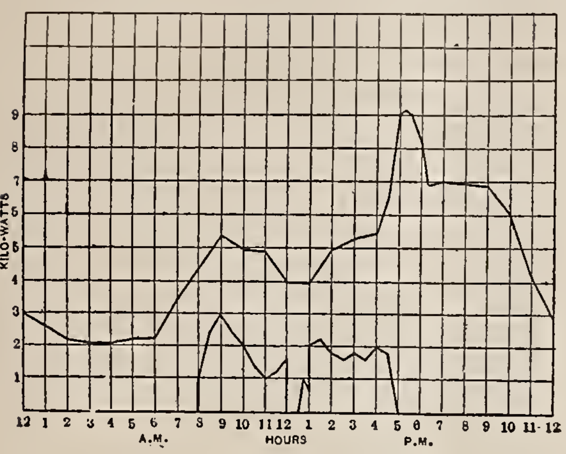


Fig. 14.—PRINTERS
Multiply by 1,000 to obtain station load.
Multiply by 5.5 to obtain consumer's load.
Kilowatt-hours per year, 24,926.
Connected load, 27.5 horse-power.
Maximum demand, 16.5 kilowatts.
Ratio of maximum demand to consumer's load on station peak—off.
Load factor, 17.3 per cent.
Station load factor, 32.4 per cent.

nitrogen to a little further extent than other products herein mentioned. At Notodden, in Norway, where power is sold as low as $6.44 per kilowatt-year, and is sold to the nitrate company at $7.97 per kilowatt-year, the Birkeland-Eyde process is in successful operation. This process comprises the production of a magnetically controlled arc in a current of ordinary air. The nitric oxide formed by the arc action

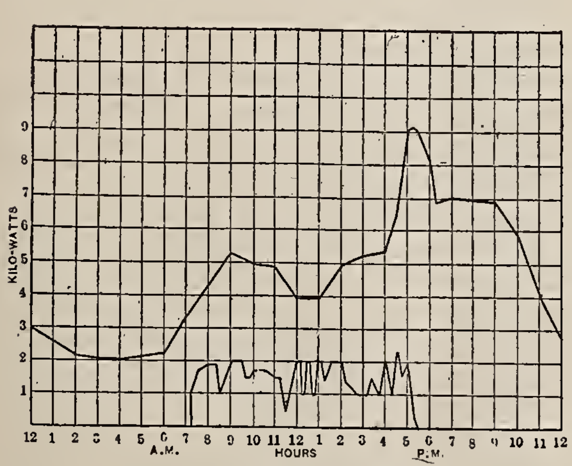


Fig. 15.—ROASTING
Multiply by 1,000 to obtain station load.
Multiply by 2.5 to obtain consumer's load.
Kilowatt-hours per year, 7,341.
Connected load, 7.5 horse-power.
Maximum demand, 6 kilowatts.
Ratio of maximum demand to consumer's load on station peak, 16.6 per cent.
Load factor, 14 per cent.
Station load factor, 32.4 per cent.

is conducted into lime with the production of calcium nitrate. This nitrate is produced at a cost of slightly over $25 per ton and successfully competes with Chili saltpetre in Norway. One and three-tenths kilowatt-years are found necessary to make one ton of calcium nitrate, hence the cost of power and lime used amounts to not quite one-half the total cost of the product. Labor is very much cheaper in Norway than in the United States; therefore, in considering the manufacture of nitrate here with power at the Norwegian price, a considerable sum must be added to the cost. The selling price will be determined by the cost of Chili saltpetre, which varies from $35 to $43 per ton at our seaboard.

The Frank and Caro process for fixation of nitrogen is chemically quite different. Calcium carbide, while still hot from its production, is treated with atmospheric nitrogen, producing calcium cyanamide. This substance is used directly as fertilizer, being in effect similar to ammonia salts. On basis of available nitrogen content, it is produced in Europe slightly cheaper than the nitrate, but the product is not so permanent and meets more prejudice. The process itself is not so

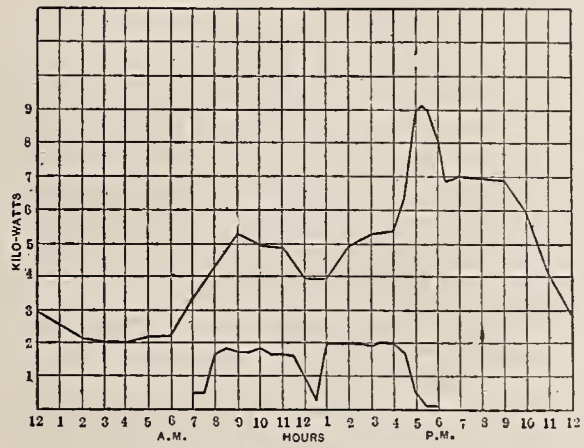


Fig. 16.—SHOE FACTORY
Multiply by 1,000 to obtain station load.
Multiply by 32 to obtain consumer's load.
Kilowatt-hours per year, 137,983.
Connected load, 111.5 horse-power.
Maximum demand, 65 kilowatts.
Ratio of maximum demand to consumer's load on station peak, 9 per cent.
Load factor, 24.2 per cent.
Station load factor, 32.4 per cent.

simple as the other, but is nevertheless attaining considerable success. The cyanamide is a direct source of ammonia, which will undoubtedly be important in the future. It should be taken into account that the Chili nitrate beds are not inexhaustible and that future generations must look to the atmosphere as their source of plant food. Therefore a successful process for the economical fixation of nitrogen will become a permanent industry.

The manufacture of oxygen, while of small magnitude at the present time, deserves more than passing mention, for the reason that if oxygen could be supplied at a very low price the demand would be very large on account of its value in metallurgical operations. Unfortunately, cheap oxygen must be at hand before great development can be looked for and, *vice versa*, great demand for oxygen must exist before there is much inducement for any one to establish

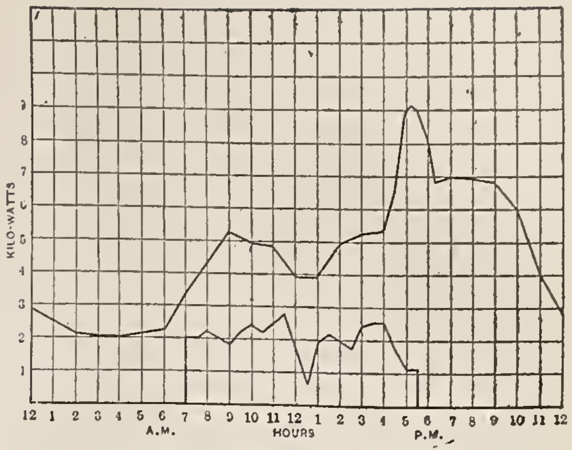


Fig. 17.—STRUCTURAL-STEEL SHOP
Multiply by 1,000 to obtain station load.
Multiply by 16 to obtain consumer's load.
Kilowatt-hours per year, 81,732.
Connected load, 75 horse-power.
Maximum demand, 45 kilowatts.
Ratio of maximum demand to consumer's load on station peak, 39 per cent.
Load factor, 20.7 per cent.
Station load factor, 32.4 per cent.

large works for its manufacture. With cheap power, the electrolytic decomposition of water will furnish both oxygen and hydrogen, which should be easily marketable in metal-working centres. The hydrogen would be available for most purposes for which any fuel gas is available, with the possible exception of gas engines. The present gas engine depends upon initial compression for its economy, and, unfortunately, a mixture of hydrogen and air will not withstand high compression without preignition. For mantle-burners, gas furnaces, and the like, hydrogen is an ideal fuel, on account of the high temperature of its flame and the harmless product of its combustion.

It is possible that in some cases power would not be entirely shut off during the peak. If from 40 to 60 per cent. of the total power could be

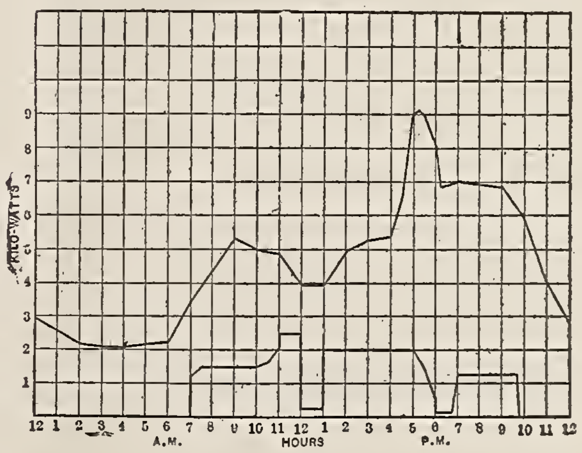


Fig. 18.—TYPE FOUNDRY
Multiply by 1,000 to obtain station load.
Multiply by 10 to obtain consumer's load.
Kilowatt-hours per year, 34,560.
Connected load, 123 horse-power.
Maximum demand, 29.7 kilowatts.
Ratio of maximum demand to consumer's load on station peak, 60 per cent.
Load factor, 13 per cent.
Station load factor, 32.4 per cent.

supplied during this time, the field of possible operations would be greatly broadened, because, in some of the processes excluded by their nature from consideration here, a reduction

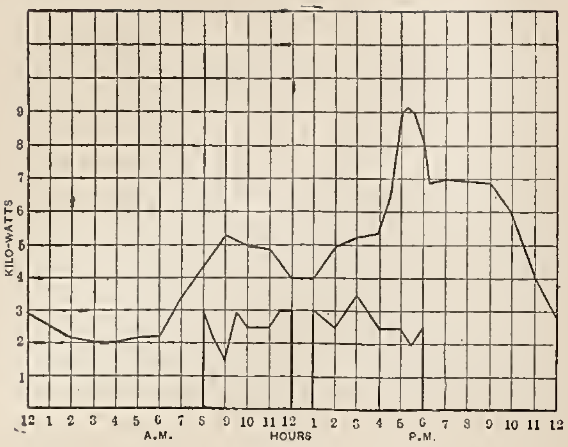


Fig. 19.—WAGON MANUFACTURER

Multiply by 1,000 to obtain station load.
Multiply by 8 to obtain consumer's load.
Kilowatt-hours per year, 30,000.
Connected load, 33.75 horse-power.
Maximum demand, 18 kilowatts.
Ratio of maximum demand to consumer's lode on tation peak, 75 per cent.
Load factor, 19 per cent.
Station load factor, 32.4 per cent.

of the current is not attended with the serious consequences that accompany a complete shutdown. Such processes include the manufacture of chlorine and soda, aluminum, sodium, carbon bi-sulphate, chlorate of potash, and various other compounds of lesser importance.

The conclusion, which is reached by consideration of this subject, is that if power companies can supply power off the peak for 20 hours or more per day, at prices below $10 per kilowatt-year, they should be able to interest the electrochemists.

We wish to add that for inland territory the freight rate on Chili saltpetre is very high, and this should be taken into consideration when figuring the revenue to be derived from this class of power.

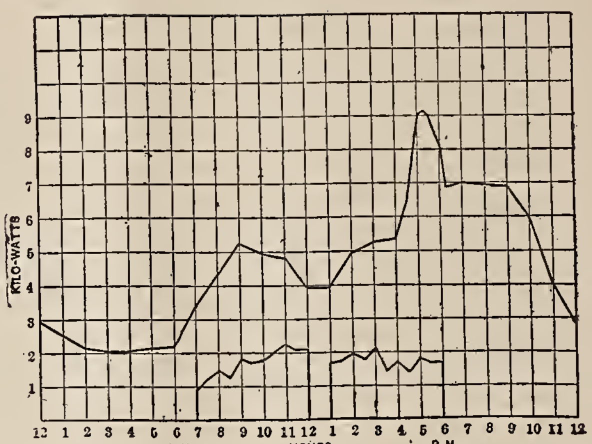


Fig. 20.—WOOD-WORKING

Multiply by 1,000 to obtain station load.
Multiply by 3.75 to obtain consumer's load.
Kilowatt-hours per year, 66,200.
Connected load, 129.5 horse-power.
Maximum demand, 44 kilowatts.
Ratio of maximum demand to consumer's load on station peak, 55 per cent.
Load factor, 17 per cent.
Station load factor, 32.4 per cent.

Engineering Responsibility

An Inquiry as to the Causes of Failure and Methods of Improvement

CHAS. B. DUDLEY

Few fields of study are more fruitful of results and lead to more genuine progress than a study of the causes of failures. Such studies may be unpleasant and disagreeable, they may at times be even disheartening, but the man who would make substantial advances must heed the lessons which his failures teach. It is true that valuable information can be obtained likewise from a study of materials which have given successful service. And ofttimes, when attacking a new problem, a comparison of the properties and characteristics of those parts of a structure which have behaved well in service with the characteristics and properties of those which have failed in the same service, is a most satisfactory method of approach. And yet, it is doubtful whether the study of failure does not give the more positive information. When an experiment or a construction has proved successful, we are naturally most interested in the result, and do not usually spend time and thought and study over the details which have led to our success. On the other hand, if our experiment or construction is a failure, the cause of the failure is immediately sought for, every detail is questioned, and it is this study of the details which broadens our knowledge.*

WHO IS RESPONSIBLE?

Closely connected with the query as to the cause of failures is the ofttimes more important question, who is responsible for the failure? If the matter in hand is an experiment which we are making for our own information, the question of responsibility is small and is practically swallowed up in the cognate question of the cause of the failure. But if, on the other hand, the failure involves the loss of human life or the destruction of valuable property, the question of responsibility may be very grave. And if we may trust our observation, the location of the responsibility for failure is not always an easy matter.

In our studies of failed and broken parts in connection with our work at Altoona for now some years, we have been gradually led to ascribe failures to one or more of the four following causes, viz., to bad material, bad workmanship, bad or faulty design or to unfair treatment.

BAD MATERIAL

Material is bad, and may justly be charged with being the cause of failure when it is different from what those who put it in service had a reasonable right to expect it to be. A rail with a bad pipe in the head, an axle made from a badly segregated bloom, a piece of concrete in which the materials are improperly mixed or contain not enough or inferior cement, are all examples of bad material, and if failure comes the failure may justly be charged to the material.

Factor of Safety.—The query may naturally arise here, ought not the factor of safety employed to be sufficient to care for the uncertainties of material, so that the total output of a works could be made use of in service. Undoubtedly there is a necessary relation between the factor of safety and some of the uncertainties of manufacture, but it can hardly be allowed that the producer should then throw upon the consumer all the uncertainties of material. We cannot help thinking that our definition of bad material is sound, viz.: Material is bad when it is different from what those who put it into service had a reasonable right to expect it to be. If the material is bought on specifications it is reasonable that it should be what the specifications call for. And even if it is bought on indefinite verbal or written order such material should be supplied as the buyer had a reasonable right to expect would be furnished. But why is there ever any difficulty between the producer and consumer about material? The price is agreed upon when the order is taken and the quality of the material is

*Condensed from the annual presidential address delivered before the American Society for Testing Materials, June 29, 1909.

either specified or understood. Why, then, does not the producer always furnish good material?

Price Factor.—First and perhaps most important is the price. It is constantly urged that the consumer will not pay the price requisite to secure the materials desired. No information is usually given as to how far the wished-for price, requisite to secure such good materials as the producer would like to furnish, covers a desire for large profits and consequently consumers have always been a little slow in attaching much weight to this excuse. Prices are largely determined by competition, and in the absence of something more than a verbal statement from the producer that better materials would be furnished at a higher price, he would be a bold purchasing agent that would pay the higher rate. On the other hand it is undoubted that competition is the antagonist of quality, and where materials are bought without reasonable specifications rigidly enforced there is unquestionably much weight in the contention of the producer.

Another Excuse.—Another reason or excuse for poor materials is that processes and methods of manufacture do not always and every time yield the desired first quality product. Strive as the manufacturer may, the works always turn out some material that is inferior. Taking one illustration from the steel industry, it is well known that every heat is not equally as good as every other, and that a part of each ingot is inferior to the remainder of it. Of course, all of this inferior part that cannot be sold must necessarily remain as scrap, to be worked over again, with the result the manufacturing cost of the marketable product is necessarily increased. Hence the tendency to crowd the limits and force upon the purchaser all the merchantable material possible, even though some of it may be inferior.

Functions Usurped.—Another and most pernicious excuse for furnishing bad materials is the attempt so common on the part of producers to usurp the legitimate functions of both the consumer and his expert. This manifests itself in the statement, so commonly made by those furnishing material, that it is good enough for the purpose, thus arrogating to themselves the right to decide not only how the material shall be made, but also what kind of material the consumer and his engineer shall use. Pernicious though this custom may be, a good deal may be said in palliation of it. The practice is the outgrowth of an historical situation. In the earlier days, when the consumption of materials was only a fraction of what it is at present, the producer of any material was supposed to know not only how to manufacture it, but also its characteristics, and how it would behave in service, and consequently consumers who in those days had scarcely begun to study for themselves the behavior of materials in service, naturally turned to the manufacturers for counsel as to what materials to use. This practice is still in vogue, and it is to be confessed that, where it is employed, no legitimate criticism of the producer can be made if he urges that the material is good enough for the purpose. On the other hand, as time progressed, and large consumers began to study for themselves the behavior of materials in service, as they began to employ their own experts, as testing machines and laboratories began to increase, as, indeed, a society for testing materials came into existence and knowledge of the properties and characteristics of materials began to widen, it is evident that the situation has changed and that where materials are bought on definite specifications, the voice of the producer as to quality is no longer potent, and that the old excuse for inferior materials, that they are good enough for the purpose, is no longer entitled to consideration or weight. We are entirely ready to allow that the study of materials, during both the process of manufacture and their behavior while they are in service, is a legitimate field of activity for both producer and consumer, and that while specifications are being made there should be the heartiest co-operation on the part of both; but the specification having been decided on and the contract placed in accordance therewith, there really seems to be very little room left for excuse for furnishing materials that do not meet the requirements, because they are, in the judgment of the producer, good enough for the purpose.

BAD WORKMANSHIP

That bad workmanship is a far too frequent cause of failures is common experience. The tendency to slight the job is almost universal. A rivet or a bolt is left out, with consequent increased strain on those which are actually put in, a forging does not fill out the pattern, or the metal is burned, or a weld is defective. We knew a case once where the construction on a passenger coach involved the safety of human life, and where the drawings required that there should be two nuts on a bolt and the end of the bolt riveted over. After the cars had been in service a few weeks and some minor repairs were being made, it was discovered that the bolts originally used in a number of the cars were too short, that the second nut only grasped one or two threads, and that the remaining space in the nut had been filled with putty, so manipulated and stained as to give the appearance of the riveted end which the drawings called for. There is little doubt that the experience of each of you will furnish quantities of cases of bad workmanship, and we have known engineers who did not hesitate to declare that bad workmanship was the principal cause of failures in service.

No doubt many will claim that inferior or insufficient compensation is the most fruitful cause of poor quality of work at the hands of those who, in our industrial system, play the part of hewers of wood and drawers of water. But if we are right, the experience of the last few years has not seemed to confirm this view. If this was the real explanation it would seem to necessarily follow that voluntary increase in wages would bring an increase in efficiency. On the other hand, if we may trust the indications that we have been able to gather, the increase in efficiency following voluntary increase in wages has been most disappointing. We must apparently look further for the real reason for poor workmanship.

Matters of Compensation.—In our judgment, the method of compensation for work performed has a direct and most important influence on the quality of the service rendered. We refer especially to the piecework system in those places where it is applicable, and to the payment of all interested in proportion to the amount of successful output, which is so common in the steel industry. Both these methods of compensation stimulate output at the expense of quality, and it is not at all strange, perhaps, that after constructions have found their way into service, we should not infrequently find evidences of the haste, the slurring over, and the inferior workmanship which these methods have necessarily done so much to stimulate. We are not at all prepared to suggest any substitute for them, and we are, and have been for many years, an advocate of them from the standpoint of successful management; but it is folly for us to close our eyes to the fact that the piecework and other successful output methods of compensation of workingmen are antagonistic to quality of work, and that, despite all our efforts to the contrary, they may justly be held responsible for some of our engineering failures.

DESIGN

It is evident that the engineer who makes or finally decides upon the design of any structure carries a heavy load of responsibility. He is first in the field and practically tells all who

follow what is to be done. He must decide not only the kind of material that is to be used, but also the amount or sizes, and how it shall be disposed. His realm embraces every kind of structure, from the foundation of a bridge or building to the most minute detail of a locomotive or car. His knowledge of the properties of materials used in construction must necessarily be broad and comprehensive.

Two Difficulties.—The engineer who makes the design labors under two very serious difficulties. First, it is not possible, many times, to compute the strains to which the whole or parts of the structure will be subjected. Perhaps we can make this point clear best by considering the locomotive driving axle. The strains produced, when we regard the locomotive as a vehicle, are simple and easily determined. So likewise the bending moment produced by the action of the steam on the piston, as well as the torsion strain produced by the crank. But who can tell the bending moment produced by the lurch when the wheel strikes a curve at high speed? Who can even give a guess at the strain produced when the brake is applied, making an emergency stop at 60 miles an hour? Moreover, the tendency of the times is toward larger and larger structures. And as the parts increase in size, would any of us be willing to say that the strains in each part would increase directly proportional to the increase in size of the whole structure, or that a proportional increase in size of any given part would so successfully meet the increased strains as did the corresponding smaller parts of the original structure? The engineer who makes the design, perhaps more often than any of us, is at the end of his knowledge, and if failure comes, due to defective or faulty designs, deserves in our opinion, more sympathy than any one else involved.

Designer's Troubles.—But the designer labors under another serious difficulty. He is often overruled and prevented from doing what his judgment prompts him to do, in the interests of safety, by those who control expenses. The construction he would like to use costs more, and the management for economic reasons demands something less expensive. Of course, under these conditions much responsibility is taken off the designer. And while we are ready to allow that some check is desirable, since those who make the design are, after all, human and naturally will take care of themselves, we cannot but feel that this check should be sparingly applied in all places where safety to human life is involved.

UNFAIR TREATMENT

As already indicated, there is a natural disposition on the part of each of us to relieve ourselves from blame and put the fault on some one else, and if our observation is worth anything there is no field of parceling out desserts among those involved in failures and the responsibility therefor, more fertile than this one of unfair treatment. If a rail breaks or fails in service there was, says the rail maker, something wrong with the track or with the locomotives or cars that run over it. If a car wheel breaks or fails to give the guaranteed mileage, the track was too rough, the use of the brakes too severe, or the loading too heavy, and so on. Far be it from us to say that unfair usage is not many times a legitimate explanation of failures. If a freight locomotive, designed to haul a heavy load at 20 miles an hour, is used at times on a passenger train at 40 miles an hour, and in so doing shakes herself to pieces, the fault is certainly not in the materials, nor in the workmanship, nor in the design, but in the unfair use. These examples might be multiplied to almost any extent, but perhaps enough has been said to make the point clear.

There is, however, another phase of this part of our subject. Unfair treatment is very much broader than the obvious misuse of a bridge or of a moving vehicle. The materials entering into a structure may be unfairly treated. If the calculated strains are too high, or, what amounts to the same thing, too low a factor of safety is employed, materials are unfairly used. Still further, where a structure is a composite it may, and undoubtedly does, often happen that the elements making up the composite are unfairly treated, as when for economic reasons, not enough money is spent to properly install the structure. For example, a steel rail called upon to do its work supported by too few ties, insufficient ballast and a badly drained sub-grade, is unfairly treated. Moreover, the state of repair in which structures are maintained is clearly an element in their fair treatment. If not enough money is spent in repairs and parts become weakened by decay, corrosion or wear to such an extent that failure results, it is entirely obvious that the failure must be attributed to unfair treatment.

Rail Failures.—It will be remembered that within the past two or three years there has been pretty much outcry in regard to broken steel rails, and the steel rail manufacturers have, in the technical press, been quite severaly called to account for their shortcomings. Indeed, from this platform, in the last annual address, some statements were made indicating that it was believed that the maximum fiber stress in the 100-lb. rail under present conditions of wheel loads and speed was not over 12,500 lb. per square inch. Some two months ago we received a letter from one of the ablest metallurgical engineers connected with steel rail manufacture in this country, in which this statement was very seriously called in question. The writer of the letter figured that under many conditions the fiber stress might be double the figure given, and under extreme, but still possible conditions, the fiber stress might reach nearly four times this figure. The obvious conclusion was, although this was not stated in the letter, that it was these extreme fiber stresses, this unfair treatment, which caused the rails to break.

We may further note the experience of the Atchison, Topeka & Santa Fe railroad with broken rails on different sub-grades. This road has some 227 miles of roadbed which were sandy, porous and well drained, and 91 miles which were largely clay of a kind that holds water. The traffic was the same over both portions and the rail all 85-lb. rail. The rail breakages in one year were two and a half times greater per mile of track on the clay sub-grade than they were on the sandy sub-grade. Mr. Wells, the general manager of the road, was kind enough to say, in communicating this information, that these facts seemed to confirm the statement made in last year's annual address that "there are indications that rail failures are a question of geography." More to the point for our present discussion is the obvious conclusion that the use of rails on clay sub-grade full of water without sufficient porous ballast is unfair treatment, and that breakages under such conditions cannot justly be said to be the fault of the rail.

It is difficult for us to see how any one who is responsible for safety in structures dare at the present time put material into these structures which has not been bought on carefully prepared specifications, and which, before acceptance, has not been rigidly inspected and tested. In time past, before consumers understood the demands which the service makes on materials, the reputation of the maker was perhaps the best safeguard known for good materials and was accepted as reasonable defense in the investigation following disaster. But in these days, when the service has been so frequently questioned, when so much accumulated information is available, when experts and facilities for testing are so largely multiplied, we cannot help feeling that the management that puts materials into service, especially where safety is in-

volved, without careful and conscientious inspection and testing, is taking a risk that it is no longer entitled to assume. It is gratifying to be able to see that, as the years go by, there is a constant and steady growth in this field. And while the ground is still far from being covered and the number of standard specifications still far too small, each year brings some progress, some steps forward.

Necessity of Investigation.—Bad workmanship and bad materials can apparently be so controlled as to secure safety by sufficient supervision and by having proper specification, with rigid inspection and test. But how about the unfair treatment of materials, or the structure made from them? Here no supervision beyond some meager legislative enactments and the condemnation of public opinion in case of disaster are possible. It is, of course, true that those in charge of the construction and operation of utilities in which the public safety is involved are constantly face to face with the possibilities of heavy losses in the way of damages for accidents, and no doubt this is a most powerful check against unfair treatment. But it has seemed to us for a long time that the producers of material have far too much neglected their opportunities. Surely it is as legitimate that the producer shall study the treatment his material gets in service as that the consumer should study the methods by which that material is made. It may take the consumer a few years to become familiar with the idea of being told that he has not treated material fairly, since he is undoubtedly accustomed now to thinking that he can do what he wishes with what he has bought and paid for; but we are confident there would have been fewer complaints of material in the past if the method we have suggested had been in vogue. It is common experience that the truth is reached with much greater certainty and speed if a problem is attacked by two parties who approach it from different standpoints and are actuated by antagonistic interests.

What shall we say of the engineer who makes the design? We have already described his difficulties, pointed out his limitations and expressed our sympathy with him in his chance failures. The truth is we are using materials in construction without sufficient knowledge. There is crying need for experiment. The factor of safety everywhere is largely a guess. We cannot help feeling that no better use could be made of some small fraction of the millions that have been accumulated by individuals in connection with our great industries during the past half century than in the establishment of a bureau of engineering research. Who will avail himself of this magnificent opportunity?

Just a word in conclusion. No one can contemplate the situation which we have been trying to discuss without being impressed with the diverse and ofttimes antagonistic interests involved. The producer of material is anxious to secure the largest amount of successful output and the greatest possible amount of reward therefor. The consumer wants to limit this by restrictions as to quality and to obtain the material at the lowest possible figure. The workman's interest is to secure the maximum of pay for the minimum of effort, and in this struggle it may perchance happen that the quality of work suffers. The employers' interests are clearly the reverse of the workman's, and so on. The foundations of these diverse interests are of course very deep, and with the present organization of society it is not easy to see how they are to be obliterated or their antagonism neutralized. But we beg to make one suggestion. Would not an infusion of genuine conscientiousness into our industrial life bring an amelioration? If a little less energy were expended in the mad race for wealth and a little more zeal manifested in maintaining the rugged virtues of honesty, integrity and fair dealing, would not some of the friction and contention of our present commercial life disappear? We must all live together, and surely harmony is better than contention. There are some things in life of more value than money.

The Advantage of Group or Individual Drive in Certain Installations

C. A. GRAVES

Power Engineer, Brooklyn Edison Co.

Probably every power user who has been approached by central station representatives or motor salesmen has ofen heard the phrase, "You can reduce your bills by installing individual motor drive." *

It is the object of this article to show why group or individual drive is preferable, and also give some examples of actual practice, which will serve as guides to assist others in advising prospective customers how to secure the most economical installation. Each installation is a separate problem in which are the following factors; the degree in which these different factors predominate determines the type of drive:

Installation cost.
Price of current.
Machine load factor.
Shafting friction.
Motor efficiency.
Maintenance.
Speed variation or uniformity
Time to make change.
Floor space.
Character of work.

Each factor will be taken up in detail, beginning with

COST OF INSTALLATION

This is the principal factor that prevents the installation of the individual motor drive, as few concerns have been willing to spend the capital to make an unknown saving in operating expenses.

The cost of group-drive installations, including the motor, shafting, and belting, varies from $20 to $60 per horse-power of motor; the latter figures for small-size motors.

The individual drive, where motors are installed on the floor or ceiling and belted to the machines, costs from $40 to $60 per motor-horse-power.

Where the motors are fastened to the machine by bolts or brackets, and gears or silent chains used, the cost is approximately $80 per motor-horse-power for small motors.

In subsequent data and charts, the fixed charges are figured at 15 per cent. on the investments for both individual and group drive.

The amount of money to be spent for an individual-drive installation to obtain the greatest economy depends upon the price of the current, the

*N. E. L. A. 1909.

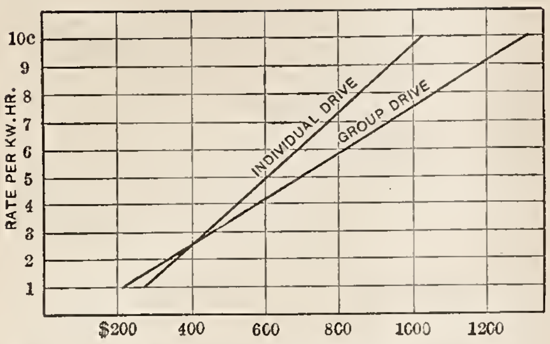


Fig. 1.—ANNUAL COST OF OPERATING PRINTING ESTABLISHMENTS

average number of hours per day the different machines are in operation, and the friction of the shafting.

PRICE OF CURRENT

While the individual motor installation increases the horse-power connected over a group-drive installation, it does not change the maximum demand materially. Individual drive has a disadvantage, however, with those contracts in which the discount allowed is based on the connected motor load or the maximum demand is figured on a percentage of the connected load; also if the minimum monthly guarantee is based on the connected horse-power. The decreased current consumption of the individual-drive plant will not earn as low an average rate as the same plant having group drive, according to a great many power contracts; and the lower the rate, the less advantageous is the individual motor drive, as the fixed charges are a large part of the cost.

Fig. 1 shows the relative yearly cost, at different rates, for running a printing establishment by group drive and individual motor drive. It will be seen that at a rate of 2.4 cents per klowatt-hour the costs are equal, while with lower rates the group drive is the cheaper.

LOAD FACTOR OF MACHINES

The average plant manager has a wrong idea regarding the length of time his various machines are in operation, and to illustrate the case, the results of a test on the principal machines in a wagon and truck manufacturing plant are given in Table I. These figures are the average of a 5-days' test and check very closely with the monthly meter readings.

The term "load factor" as used refers to the average number of hours the machines run per day, 10 hours being considered 100 per cent.

It is expensive to have machines used but a short time daily, and managers are continually trying to keep them busy, but even in the best-managed plant or with automatic machines, in textile mills and similar service the machines are not in operation over 85 per cent. of the time.

In one of our large manufacturing establishments where an isolated plant was superseded by central station service, and a rotary converter installed on the premises, having in mind the manager's hobby to work

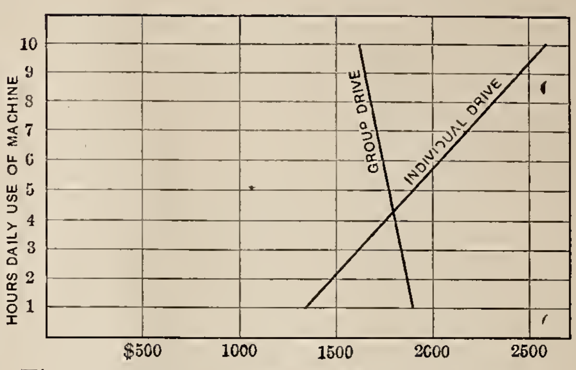


Fig. 2.—ANNUAL COST OF FRICTION AND FIXED CHARGES IN WOOD-WORKING PLANT

the machines as hard as possible, the voltage was worked up gradually, increasing the speed of the motors, and the central station service received the credit for the increased output.

In determining the load factor of an individual group of machines a record of the daily or monthly output compared with the maximum output will be helpful.

Fig. 2 shows the effect the load factor has on the choice of the type of drive. It is plotted for the wagon and truck manufacturing company before mentioned. On this chart only the current required to run the motors and shafting per year and the fixed charges per year are considered in the group drive, it being assumed that the shafting would be run 10 hours per day, and that when a machine is running its loose pulley is absorbing no power. With the individual drive the motors are run only when the particular machines to which they are connected are in use, the current required to drive the machine being the same in both instances. It will be seen that at about 4.5 hours' use per day of the individual motors,

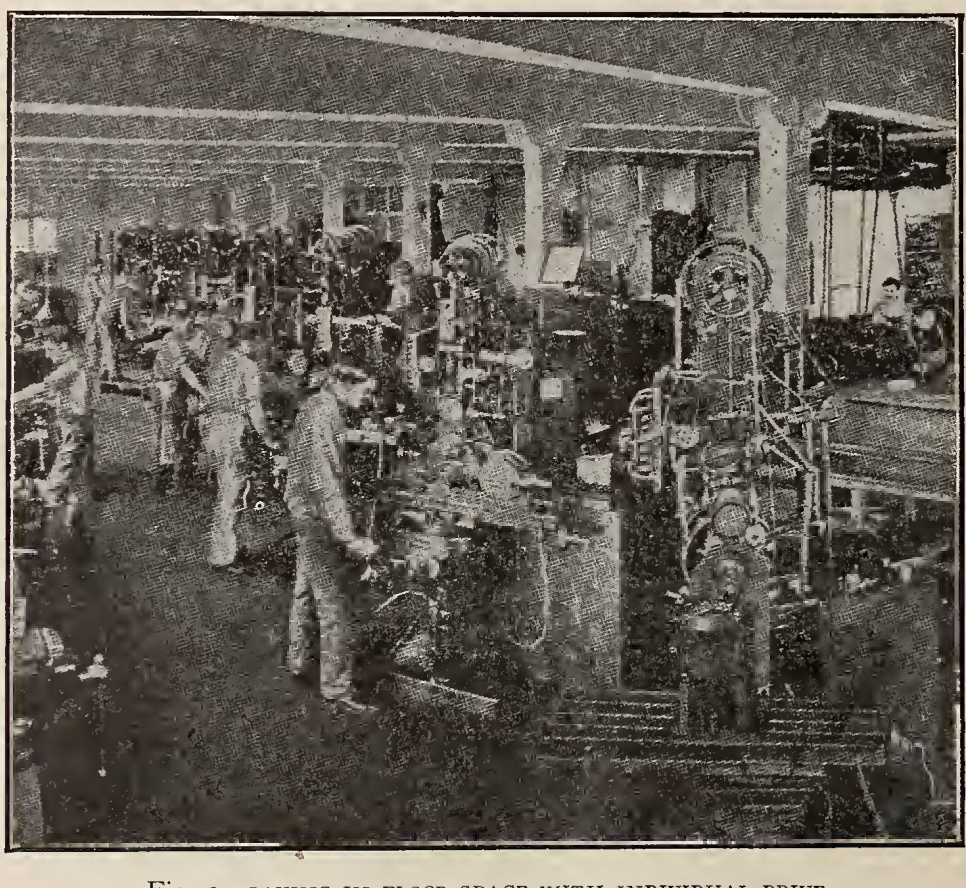


Fig. 3—SAVING IN FLOOR SPACE WITH INDIVIDUAL DRIVE

TABLE I.
KILOWATT-HOURS PER DAY USED BY INDIVIDUAL MACHINES.
AVERAGE DAY'S RUN, 9.5 HOURS = 570 MINUTES.

	Per Cent. of Time in Day Machine is Run	Number of Starts per Day	Minutes Average Run	* Min. Kw. Load	* Max. Kw. Load	* Kw-Hours per Day
Jointer	1/5	60	2.0	1.6	2.5	4.0
Cut-off Saw	1/40	22	0.6	2.0	4.6	0.7
Rip saw	1/7	34	2.2	2.0	8.0	5.2
Planer, 36-inch	1/5	22	4.6	5.0	15.0	13.4
Boring Machine	1/2	12	20.0	0.8	2.0	5.2
Band saw	1/4	56	2.4	1.1	2.3	3.6
Shaper	1/5	16	6.4	2.2	3.5	5.0
Bradley hammer	1/9	18	3.3	1.0	5.0	3.5
Mortising machine	1/60	6	1.4	3.4	6.0	1.0
Tanging machine	1/55	2	5.5	0.8	2.0	0.4
Rounder	1/20	8	3.0	2.3	3.3	1.0
24-inch emery wheel	1/9	8	5.0	0.7	3.0	2.0
Elevator (5-ton)	1/5	36	2.0	0.0	12.0	5.0
2 drill presses	All day	..	570.0	...	...	8.0
Blower	"	..	570.0	1.8	2.0	18.0
Shafting	"	..	570.0	...	1.4	13.3
		300				89.3 26 days

*Includes current required to run motors.
89.3 kilowatt hours × 26 days = 2321 kilowatt-hours.
Meter readings for average month = 2300 kilowatt-hours.

the costs of running with a rate of 5.5 cents equals the cost of running the motor and shafting, and that for over 4.5 hours' use, the group drive is the cheaper.

SHAFTING FRICTION

The usual method of denoting the power necessary to drive shafting has been in a percentage of the total power used, or in horse-power per hundred-foot length. In order to determine more definitely the power absorbed by shafting, the motor testers in Brooklyn weer instructed, in addition to the usual data, to count the hangers in which the shaft revolved and also the loose pulleys on the shafting and countershafting over which belts were passing. It was found that the average loose pulley with belt absorbed as much power as a hanger, so the term "bearing" as used includes both hangers and loose pulleys.

Table II shows the watts per bearing required to drive shafting for different classes of work.

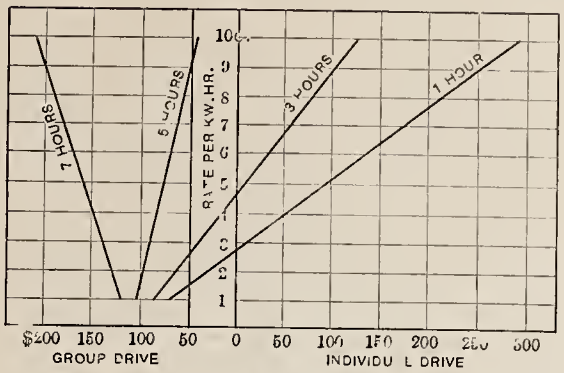


Fig. 4.—RELATIVE ANNUAL SAVING IN SEWING MACHINES

TABLE II.

Number of Installations Tested	Class of Work	Max. Watts	Min. Watts	Avr. Watts	R. P. M. of Shafting
100	Various	240	11	76	150 to 300
50	Machine	177	19	49	150 " 300
25	Sewing machines	27	7	20	350 " 400
6	Stone yards	183	93	143	100 " 250
7	Wood working	237	11	87	250 " 600

The maximum figures were in some cases obtained on shafting that appeared to be well cared for. In one test, not noted, a countershaft having two hangers was found to require nearly a horse-power to drive and did not become heated. The minimum figures were obtained on shafting with roller bearings.

EFFICIENCY OF MOTORS

In investigating complaints, also to obtain data for the power bureau, tests were made, for a period, on all motors of two h.p. and over, and there were discovered rather startling variations in current consumption for motors running free, as Table III will show.

TABLE III.

Hp. of Motor	Number Tested	Max. Watts.	Min. Watts.	Avr. Watts.
1.0	2	161	119	140
2.0	20	495	140	252
3.0	30	708	229	401
5.0	122	960	237	584
7.5	33	1298	430	738
10.0	36	1350	683	939
15.0	22	2596	940	1404
20.0	20	3276	1053	1598
30.0	8	3900	1326	2042
50.0	4	5900	2760	3903
75.0	1	....	....	4740

The figures obtained in the Maximum Watt column were usually due to improper care of the bearings and adjustment of the brushes. Slow-speed motors were found to be more efficient than the moderate or high-speed type, and it is usually cheaper, in three years' run, to install a slow-speed motor and belt it direct to a main line shaft, than to erect a countershaft and use a moderate-speed motor; therefore our agents are instructed to quote slow-speed motor prices to prospective customers. While highly efficient motors are desirable for group drive, a rugged motor is important for individual drive.

MAINTENANCE

In small shops each operator is expected to take care of the machine on which he works, and as a result some are kept well oiled, and others are looked after indifferently. If a belt needs attention, the one operating the machine must attend to it. In case individual direct-current motors are to be considered, this item of maintenance becomes a large one, as it would be necessary in some instances to employ an additional man to spend part of his time on the motor equipment, while with the group drive the one or two larger motors would be taken care of by the foreman. In larger plants, a man is usually employed for the specific purpose of caring for the shafting and belts, and this man can be trained to take care of the motor equipment.

In the plant referred to later (Fig. 7), with shafting drive, a man and his helper were employed all the time oiling the bearings and repairing belts. The material used in this work amounted to $500 per year additional to the labor charge. With individual motor drive one man and a boy spend only half their time on the motors, and the material account for brushes, and the like, excluding oils, amounts to but $30 per year.

In the charts, except where it is mentioned, the item of maintenance is not figured, because no definite sum can be named.

SPEED VARIATION AND UNIFORMITY

The individual motor drive increases the output on machine tools over the cone pulleys or complicated mechanical speed-changing devices, and where speed variation is wanted no other drive should be recommended.

If strictly uniform speed is required on a group of machines, the motor may be connected to each machine by a chain drive or to a lay shaft and the machines driven from that by means of a chain or gear.

TIME TO MAKE THE CHANGES

This is an important factor in favor of the group drive, as shop managers believe they can not spare the machines long enough to have the motors attached, the usual desire being to have the electric power introduced as soon as possible; one of the talking points of the salesman being the ability to install a motor direct to the existing shaft without loss of time.

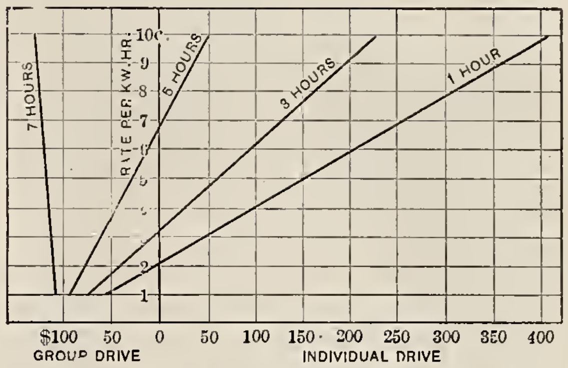


Fig. 5.—RELATIVE ANNUAL SAVING IN MACHINE SHOPS

FLOOR SPACE

If floor space is an important factor, individual motor drive will allow the arrangement of machines at any angle and thus allow more machines of certain types on the same space. Another advantage is that it separates the machine operators. A further advantage is in so arranging the machines that the light from the windows falls on the work at the proper angle. Fig. 3 shows seven machines now set in the space formerly occupied by five, and also the other advantages mentioned.

CHARACTER OF WORK

With large machine tools nothing but individual drive should be selected; and in plants having traveling cranes that move the material to the machine or the machine to the material, also in shops where cleanliness and light is important.

Group drive is preferable in considering machines that run together or machines located close together, through which materials pass in sequence.

On direct-current systems group drive should be used where there are inflammable materials or vapors, and in very dusty places the motor should be installed in an adjoining room and

a shaft extended through the partition to the various machines.

One of the talking points of an enclosed motor is thus spoiled, but a motor needs some attention, and if it is dusty and dirty it is not apt to be cared for until something happens. On the other hand, individual motor drive does away with belt holes through the floors.

To assist in planning installations the following series of charts are given in which the average figures of several hundred group-drive equipments are compared with estimated individual motor-drive equipments for doing the same work.

The installations are divided into four classes, according to their shafting friction. In the first class are placed tailors, shirt manufacturers and similar works using sewing machines.

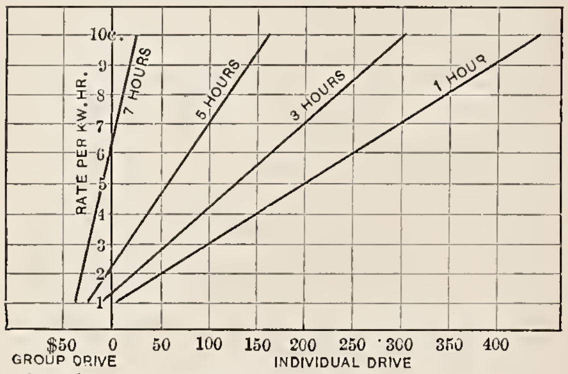


Fig. 6.—RELATIVE ANNUAL SAVING IN WOOD-WORKING SHOPS

SEWING MACHINES

The average installation consists of 34 sewing machines, each with a loose pulley, driven by a shaft revolving in 17 hangers, the shaft being belted to a 5.3-h.p. motor, the average power absorbed being 20 watts per bearing.

An individual motor equipment would cost about $20 per machine in excess of shafting drive, and Fig. 4 shows the relative advantage, in dollars saved per year, of the group or individual motor drive in this class of business, for different rates per kilowatt-hour, and average hours' use of the machines per day. It will be noted that, with average conditions, it does not pay to consider individual drive for this class of work if the machine's average daily use exceeds approximately four hours.

At a rate of 10 cents per kilowatt-hour, an average bearing in this work absorbs $6.00 worth of current in a year of 3000 hours.

MACHINE WORK

The second class comprises machine shops and similar equipments where the average bearing absorbs 49 watts in friction.

The average group drive consists of an 8.3-h.p. motor driving 12 machines and requiring 2000 watts per hour for shafting and motor friction; that is, 824 watts for the motor and 1176 watts for the 24 bearings. With individual motor drive there would be required 12 motors of a slow-speed or back-geared type, aggregating approximately 18 h.p.

Fig. 5 gives the relative amount in dollars saved per year by installing group or individual drive, for different rates of current and average dailv hours' use of the machines. If the shafting equipment is already in use, the saving by installing individual motor drive will be less than shown by the chart. It will be noted that with rates less than three cents per kilowatt-hour the group drive is the cheaper if the machines average over three hours' daily use. The shafting in a machine shop is usually maintained in better alignment, and the friction is less than in other lines of business having shafting of similar size; but even under these conditions, in this business, an average bearing absorbs, at a 10-cent rate, power amounting to $15 per year.

WOOD WORKING

The third class consists of wood-working shops with higher-speed shafting, the friction of which averages 87 watts per bearing.

The average group-drive installation consists of a 7.3-h.p. motor driving four machines and requiring 1864 watts for the shafting and motor friction; that is, 724 watts for the motor and 1140 watts for the 13 bearings. With individual motor drive there wold be required four motors, aggregating approximately 16 h.p., costing about $311 more than the group-drive equipment.

Fig. 6 shows the relative saving per year at different rates for current and hours' use of the machines. It will be noted that with five hours' or less average daily use of the machines, it is cheaper to install individual drive if the rate is above approximately two cents per kilowatt-hour. The average

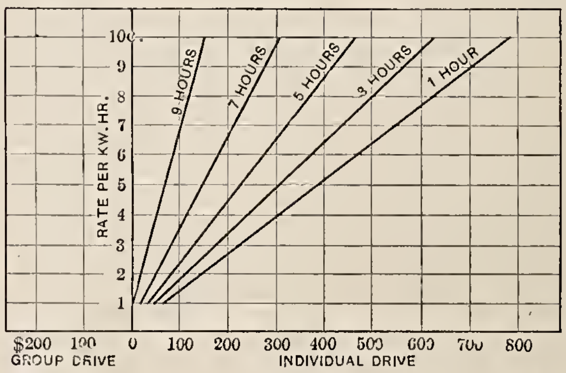


Fig. 7.—RELATIVE ANNUAL SAVING IN STONE YARDS

bearing in a wood-working establishment costs $26 per year to operate at a rate of 10 cents per kilowatt-hour.

STONE YARDS

The fourth class comprises stone yards, where the shafting is apparently left to care for itself and large friction losses are the result, so that on the average it is safe to recommend individual drive for all prices of current and hours of running, as Fig. 7 shows. The average bearing in a stone-yard installation absorbs power worth $43 per year, at a 10-cent rate.

EXAMPLES

Three actual installations are cited which have changed from group to individual drive, and one in which it was best to retain the group form of drive and reduce the shafting friction.

MACHINE WORK

The first example is a machine shop manufacturing small machines and tools. The power was transmitted through about 800 ft. of main line shafting, which was kept in excellent condition. The average load on the engine was 111 h.p., and the friction load under the best conditions was 35 h.p. Assuming this plant to be driven by a 150-h.p. motor, the cost of running it per year at different prices of current is shown in Fig. 8 by the dotted line. The cost of maintaining belts was $1,750 yearly. The interest and depreciation on a 150-h.p. motor shafting installation is figured at $600, and the current consumption would amount to 240,000 kw-hr. yearly. All

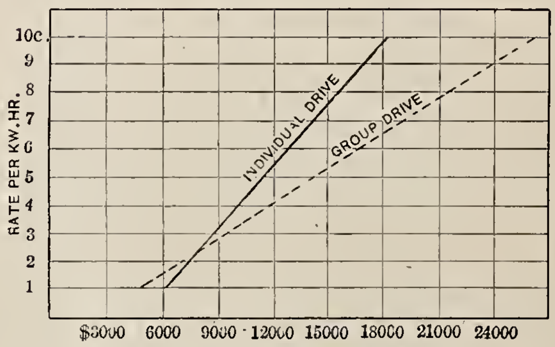


Fig. 8.—ANNUAL COSTS AT VARYING RATES IN MACHINE SHOPS

the shafting was scrapped and individual motor drive was installed, consisting of 217 direct-current motors, aggregating 450 h.p.

The cost of running this installation at different prices of current is shown in the solid line of the chart. The maintenance cost of the equipment (average of four years) is $1,280 per year. The interest and depreciation amounts to $3,750 per year. The cost of the change was approximately $20,000. The actual current consumption for power amounts to 132,200 kw-hr. per year. Several new machines were installed when the change was made, and the output has increased by a large percentage, so that the difference in yearly running costs in favor of the individual drive is greater than shown.

WOOD WORKING

The second example is a manufacturer of wagons and trucks, referred to before. The former installation consisted of a 30-h.p. and a 5-h.p. alternating-current motor belted to shafting having roller bearings. The friction load, including motors and shafting, averaged 7.2 kw. The average load was 13 kw., and the yearly consumption was 36,240 kw-hr. The cost of running the plant per year at different prices of current is shown in Fig. 9. The cost of maintaining the shafting and belts, including labor and materials, was about $600 per year. The interest and depreciation on motors and shafting amounted to $125 per year. The installation was changed to direct-current motors, the 5-h.p. group being left intact because the group was run but a few hours per month. The installation now consists of 21 motors, aggregating 100 h.p., most of the motors being fastened on the ceiling and belted to the machines. The cost of running with individual drive is also shown in Figure 9. The cost of maintaining the equipment is estimated at $500 per year. The interest and depreciation charges amount to $600 per year. The yearly consumption of current amounts to 25,200 kw-hr. The change from group to partial indi-

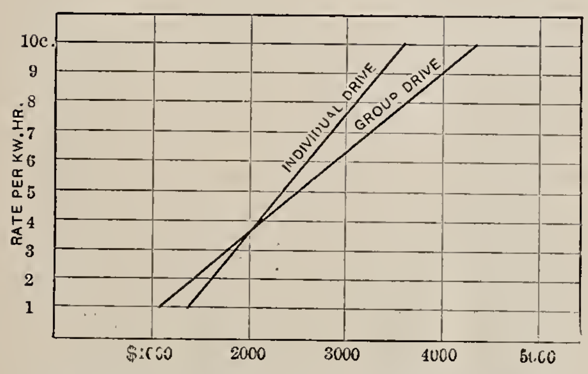


Fig. 9.—ANNUAL COSTS AT VARYING RATES IN WOOD-WORKING ESTABLISHMENTS

vidual drive was made at an expense of approximately $3,600, and the saving in current at 5.5-cent rate amounts to approximately $600 per year, but the increased fixed charges makes the net saving $230 yearly. It should be remembered that the friction of this shafting was less than the average plant would show, because of the roller bearings on the original installation, and but for that, the saving would be a greater amount.

PRINTING

The third example is that of a printer. The first installation consisted of two lines of shafting, each about 50 ft. in length, driven by a 5-h.p. and a 7.5-h.p. motor, respectively. The total cost of running this group-drive plant per year at different prices of current is shown in Fig. 1. The cost of maintaining the shafting and motors was estimated at $15 per year. The interest and depreciation on the equipment is figured at $75 per year. The actual current consumption amounted to 12,218 kw.hr. per year. The shafting was scrapped and individual motor drive was substituted, consisting of two 5-h.p., two 2-h.p., four 0.5-h.p., two 1-h.p., one 0.25-h.p.; a total of 11 motors, aggregating 18.25 h.p. The cost of running this installation per year at different prices for current is shown in Fig. 1. The maintenance cost of the equipment is estimated at $25 yearly. The interest and depreciation amounts to $165 yearly, and the actual current consumed amounted to 8263 kw. yearly. The change from group drive to individual drive was made at an expense of approximately $1,100, and the saving in current at a 6-cent rate amounts to approximately $230 per year, but the increased fixed charges reduces the net saving to $135; that is, a saving of approximately 18 per cent. was effected. The output has been materially increased also, and the proprietor says he would not use shafting drive again if no saving were effected.

SEWING MACHINES

The fourth example is that of shirt manufacturing, in which there were two factories controlled by the same firm, the first of which was operated by two motors of 13 h.p. and 15 h.p., respectively, belted to a series of shafts driving 174 sewing machines; 111 operators was the average number employed. The shafting and motor friction amounted to 9700 watts. The cost of running this group equipment per year at different rates for current is shown in Fig. 10. The cost of maintaining the equipment was estimated at $30 per year. The interest and depreciation charges were figured at $150 yearly. The actual current consumption amounted to 42,600 kw-hr. yearly.

The second factory installation was designed by a central station power man, and consists of five motors, aggregating 23 h.p. Each motor is connected by chain drive to a shaft driving a row of 30 machines. There are 149 sewing machines, and an average of 114 operators are employed. The shafting and motor friction amounts to 5000 watts. The total cost of running this five-motor group equipment per year at different rates for current is shown in Fig. 10.

While the number of machines and the operators employed at the two factories are not exactly the same, both factories have about the same output and for our purpose are considered identical.

The cost of maintaining the equip-

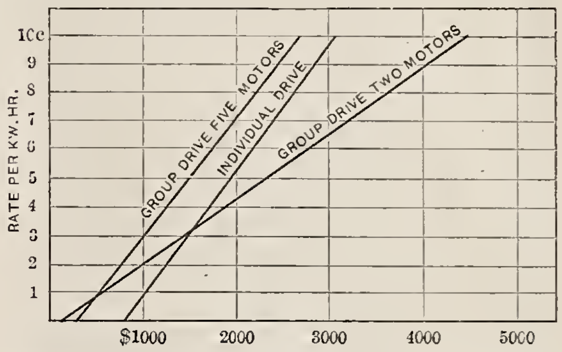


Fig. 10.—ANNUAL COSTS AT VARYING RATES IN SHIRT MANUFACTURING PLANTS

ment is estimated at $50 per year. The interest and depreciation charges amount to $210 yearly. The actual current consumption amounts to 24,240 kw-hr. yearly.

Assuming, now, that 149 individual motors were installed, with a load factor of 57 per cent. (which is the load factor of this installation), the current consumption would approximate 11,900 kw-hr. for motor friction and 10,800 kw-hr. useful work per year, making a total of 22,700 kw-hr. yearly. (The maintenance cost is estimated at $125 per year; the interest and depreciation at $675.)

It will be noted that the well-designed five-motor group drive is the cheapest with rates more than 0.5 cent per kw-hr., and that individual drive is cheaper than the two-motor group drive with rates above three cents per kw-hr. Thus, while individual drive would be cheaper than the inefficient two-motor group drive, a further study of the case by the light of the data given herein enables the customer to obtain a more efficient equipment at an expenditure of much less capital.

Science in America*

L. B. STILLWELL

The man in the street believes that we easily lead the world in science and in its practical applications, but those better informed know that we have strong rivals; that while practice in America in mechanics and the the electric arts compares favorably, as a whole, with that of any other country, the discovery of the facts upon which practice is based has been more often European than America. Even in the practical applications of physical science it happens not infrequently that we follow and do not lead. France led us in the development of the automobile. Thanks to the skill and daring of two young men from Ohio, an American aeroplane is now at the front, but Germany and France are showing the way in the construction and operation of dirigible balloons; Great Britain leads us, at present, in marine construction, and an Italian first developed, upon a practical and commercial scale, the utilization of etheric waves for transmitting intelligence to the possibilities of which attention was first directed by the research of a great German physicist.

The German empire to-day is a vast hive of industry organized in a manner of which comparatively few Americans who have not investigated the subject have anything like an adequate conception. In an interesting and very valuable paper upon "Engineering Education" read before the International Engineering Congress in St. Louis in 1904, Dr. Robert Fletcher, director of the Thayer School of Civil Engineering, Dartmouth College, said: "Realizing that even the most industrious people must have competent expert direction and that 'efficient direction of any industry today demands a large amount of technical knowledge which cannot be learned at the bench or in the shop,' the government and the people through trade associations have established hundreds of schools of applied science for instruction in all the leading industries of the empire and often many schools for the same industry."

In 1898, Prof. J. B. Johnson, M. Am. Soc. C. E., reported that "of 248 monotechnic schools in Prussia alone, more than half were voluntarily supported by various trades, as schools for apprentices; in Saxony, with 1,000,000 inhabitants, were 3 monotechnic schools, besides 10 schools of agriculture and 40 of commerce; in Hesse, schools for agriculture and sculpture, 9 for artisans, 43 for industries and 82 for design. In Baden, schools of architecture, industry, commerce, etc."

German foresight and system in the organization of educational facilities not less than the industry and the frugality of the German people, have advanced Germany within 50 years from a position of comparative poverty and obscurity to a place in the foremost rank of powerful and progressive nations. As Dr. Fletcher well says: "It is not her army of soldiers which other nations need to fear, but her armies of scientifically-trained directors of industrial enterprises and of highly-educated commercial agents."

While no other nation to-day provides as effectively as do the Germans for enlargement of the boundaries of science by original research nor for the systematic training of its people in the industrial and commercial use of scientific facts and methods, there is very much that is admirable, effective and worthy of our most careful consideration in the educational, industrial and commercial practice of some of the other great nations.

The ratio of talent and skill to raw material employed in productive work is no where higher than in France. There are still many lessons in the fields of industry and commerce that we might learn to advantage by studying British achievement. The Low Countries, Switzerland and Italy, particularly northern Italy, are utilizing as never before the energy and skill of their people in applying the discoveries of physical science to the needs of modern life, but in Germany especially are the results of the physical and chemical laboratory evidenced by tremendous advance not only in material development, but also in intellectual activity.

In 1866 there were in the United States six schools which taught engineering. The number to-day exceeds 100. Within the last decade or two, while the number of such schools has continued to increase, a greater relative advance has been made in the endowment and facilities of the older established schools.

An Act of Congress passed July 2, 1862, made provision for the establishment in the several States of colleges of agriculture and the mechanic arts, and a number of the States, from time to time, have extended substantial aid to the cause of technical education. But the one striking and unparalleled fact which stands in the foreground, when we look at the history of technical education in America, is the beneficence and public spirit of private citizens who have established and endowed so many of these splendid institutions for the training of American youth.

Of these, the school established by Stephen Van Rensselaer in 1824 was the first, and it still stands first as measured by the work of its graduates in the broad fields of civil engineering practice.

But I shall not attempt to discuss what has been accomplished. I prefer to use the time allotted to me to suggest to your minds some of the considerations which make an occasion like the present important, not only to those who are peculiarly interested in the welfare and progress of of the Rensselaer Polytechnic Institute, but to all American engineers and, indeed, to every patriotic American.

While the fact that the Rensselaer Polytechnic Institute now possesses in the Russell Sage Laboratory a plant whose potential possibilities in the training of successive classes of young engineers are obviously destined to have a far-reaching effect upon the commercial and industrial development of America, is the fact which stands out pre-eminently in the foreground to-day, there are other facts which must be sketched into the picture if we are to form anything like a correct and adequate conception of the significance of this event.

One of these facts has been suggested by what I have already said, viz., that the United States in all it has to do with science and its practical applications now meets, and must continue to meet, energetic, able and, in some cases, highly organized and increasing competition.

Hitherto the vast extent and great natural wealth of the United States, availed of by an energetic and rapidly-increasing population, under political and social conditions which, in a degree almost without precedent, have permitted, and even invited, "the emergence of the individual," have resulted in a commercial and industrial development which, as measured, for example, by miles of railroad constructed, by the value of products manufactured or by the quantities of the kindly fruits of the earth produced, has no parallel in history. But quantitative measurements are not the only tests which should be applied to past

*This title we have put upon an address by Mr. L. B. Stillwell at the dedication of the Russell Sage Laboratory of Rensselaer Polytechnic Institute, June 15, 1909.

achievement when we attempt to measure our strength for future progress. Qualitative analysis here is at least equally important. The vast natural resources of a new continent suffice for a time to cover up a multitude of sins of omission and commission by a people which develops and utilizes these resources, but as the primeval forests are cut down or burned and the accumulated fertility of the soil exhausted by use without renewal, the time approaches when those blessed with such a heritage must substitute science, skill and thrift for the hand-to-mouth methods of a frontier community.

In this process of substitution, beyond question, we have made substantial progress. The work of the Agricultural Bureau of the United States, the efforts and influence of the graduates of our agricultural colleges and the practical intelligence of our more progressive farmers have increased materially the output per acre of American farms.

Very recently a beginning has been made in the application of scientific forestry methods to the preservation and renewal of our forests.

Our mining practice, though still frightfully wasteful of life and material, has improved to some extent in recent years.

Our railroad engineers, if their work be compared with the best of foreign practice, have very much to be proud of and comparatively little to explain.

The practice of our iron and steel mills compares favorably, on the whole, with that of our great competitors abroad.

In the textile industries, while our aggregate output is large, we are as yet apparently unable to compete successfully in the production of goods of the higher and more artistic classes.

Generalization in reference to so comprehensive a subject is always hazardous, but I think it may be said with substantial justice that, broadly speaking, we in America have reached a point where scientific methods and scientifically-trained men are needed as they never have been needed before. From now on industrial and commercial progress must depend more upon refinements of practice and less upon expansion into new fields, and to the attainment of such refinements the knowledge and training which students in this laboratory, and in the laboratories of our other technical schools, will have opportunity to attain are factors fundamental and essential.

Hitherto the construction and equipment of our railroads, the building of bridges, water-works and docks, the erection, equipment, organization and operation of steel mills, the construction of buildings for all purposes, the development of mines, the design and construction of steam engines, dynamos and the manifold mechanisms of applied mechanical and electrical science have afforded ample sphere for the activities of the graduates of our technical schools. Such apparently will be the case for many years to come, and yet I would point out here the fact that training such as will be imparted in this laboratory pre-eminently fits men not only to be mechanical and electrical engineers, but also to attack with success the economic and essentially scientific problems which arise in almost every department of manufacturing industry. Decidedly it is the mental training, the ability to reason accurately from cause to effect, the sense of proportion, which count in preliminary education, rather than the incidental knowledge of facts relating to any particular science or art, and there can be no reason to doubt that if a few hundred young graduates of the Rensselaer Polytechnic Institute should take up such work, for example, as that of manufacturing woolen or cotton cloth, the effect of their scientific training would be shown inside of ten years by material improvement in quality and quantity of output and in the economy of production.

In the electrical field there is constant need of more workers and especially of better trained workers. The value of manufactured products in the United States doubled during the decade from 1895 to 1905. The output of our factories producing electrical machinery and appliances practically doubled in five years. This rate possibly was abnormal, but there is every reason to believe that for many years to come the demand for mechanical and electrical equipment will continue to increase at a rate exceeding the average rate of increase for other manufactured products, and consequently the field for trained workers in the practical applications of mechanical and electrical science is an expanding one.

The American Institute of Electrical Engineers, which I have the honor to represent upon this occasion, comprises, in round numbers, 600 members and 6,000 associate members. Its ranks are filled with graduates of our engineering schools. Much, very much, in the field of practical application has been accomplished, but even within the horizon of our present knowledge we shall need powerful reinforcements from our engineering schools in the immediate future if we are to secure and maintain that relative position in the world of progress which the natural resources of our country, the energy of our people and the opportunities afforded by our institutions demand. And beyond the horizon of our present knowledge what infinite possibilities may await keen and patient research and inventive genius!

The Rensselaer Polytechnic Institute is distinguished among our schools of science and engineering by the fact that it has never attempted to do more than it has subsequently proved itself able to accomplish with signal success. All who are interested in electrical science must rejoice that this conservatively and ably-managed institution which in the past has done so much to place the American civil engineer in the front rank of progress is now prepared under exceptionally competent and earnest direction and with adequate facilities to add to the army of trained workers in the broad field of electrical engineering.

In behalf of the Institute of Electrical Engineers, I extend hearty congratulations to the Rensselaer Polytechnic Institute upon the acquisition of these splendid laboratories which are destined beyond doubt to contribute to progress in the arts of civilization to an extent which no one at this time may attempt to measure.

The utilization of great water powers, which are now being so rapidly developed, will tend toward a combined management covering large areas. The progress which is being made in long-distance transmission is of the greatest importance in this direction. Indeed, if a layman might venture an opinion, it would be that the next era of distinct development in the electric lighting field will come as a result of the progress which your technical experts will make in economical long-distance transmission. With great power stations located in the heart of the coal districts on the one hand, or drawing their energy from great water-power plants on the other, the problem of the cheap production of current would seem to be pretty well solved. If current so produced can be economically distributed over a very large area, as indeed it is now being in many sections, the way will be open to securing the economies of a concentrated management and the advantages of large corporate issues, and that combination should result in large profit to the business venture and in a high degree of satisfaction to the security holders. The tendency of the times, it seems to me, is distinctly in the direction of recognizing the naturally monopolistic character of the electric lighting business.

Frank A. Vanderlip, before the N.E.L.A. 1909

The Effect Of Various Maintenance Conditions On The Efficiency of Illumination

A. L. EUSTICE

While the necessity and importance of laboratory performance curves of individual units is well recognized to be invaluable in assisting the illuminating and commercial engineer to arrive at approximate results when planning the layout of a new installation of lighting equipment, yet certain conditions often found in practice do not receive the consideration their importance demands, with the result that in many cases the system does not fully meet the expectation of either the owner or the designing engineer after it has been in operation for a considerable period of time.*

The cause of such a condition is self-evident when it is borne in mind that laboratory performance curves, upon which the installation is based, are always secured when the unit is operating under the most favorable conditions; a state that rarely, if ever, exists in any commercial installation. In this connection it may be well to enumerate briefly the most important conditions that bear great weight in the installation as a whole. According to the existing laboratory practice, the performance curves are secured when the unit is operating under normal voltage, current or efficiency, and when its auxiliary reflecting device—if such is used—is more accurately adjusted than is generally the case with commercial units, and, further, is in a perfectly clean condition.

The wide range in results secured from an incandescent unit when equipped with some reflecting devices—by reason of the various relative positions of the lamp and reflector—can be fully appreciated only by those who are in close touch with laboratory work. An illustration of this marked difference will be found in a unit that gives a very broad distribution when the reflector is properly adjusted, but becomes a highly concentrated distribution when mounted in some ordinary sockets and with the standard form of shade-holder; and when the non-uniformity of sockets, together with the frequent use of an improper shade-holder, is considered, the importance of the relation existing between the laboratory and commercial conditions is obvious. Further consideration should be given the non-uniformity in density and color of commercial glassware, and due allowance should be made for actual depreciation in the candle-power of the unit. Here, again, the laboratory figures on depreciation are generally secured under ideal conditions of regulation, which are different, by far, from the regulation found on many of our commercial circuits.

Although the foregoing conditions are sometimes considered when arriving at a set of figures for the installation of a lighting equipment, another very important phase of the subject is almost invariably sadly neglected, an item that has very marked effect on the satisfactory operation of a system of illumination, namely, the loss of illumination due to accumulation of dirt on the glassware of a system.

Realizing that when a system is new, with all parts clean, it is operating under ideal commercial conditions but once, the importance of a periodic and systematic maintenance on a lighting system was appreciated by the author, and hence, in order to arrive at some definite conclusion in this regard, during the last nine months an extended investigation was instituted covering a study of commercial systems with special reference to the subject. The results of this investigation, as given below, clearly indicate that the loss due to the unclean condition of commercial glassware is of such magnitude that due consideration should be given it; not only in so far as design is concerned, but also from the standpoint of operation, to say nothing of the unsightly appearance of the system itself or the effect on the interior surroundings in general. Installations are often found where the units have had no care or cleaning for an entire year, whereas if the value of systematic cleaning were recognized many systems now condemned as unsuited to the consumer's requirements would, no doubt, give entire satisfaction.

Perhaps an analogous case may be seen in natural illumination. It is certainly a matter of no difference of opinion that it is absolutely necessary to clean windows frequently to let the light in. Is it not logical, in the same degree, to clean our lighting systems frequently in order to let the light out?

In this treatment of the subject it is not the author's purpose to go into the details of the long siege of experimental work, but, rather, to present in a brief manner the final results of such work Thinking it expedient at this time to clear up finally any questions as to test methods—in view of the fact that certain incorrect methods are at the present time employed by some in the determination of *mean illumination*—the outline is herewith given, covering the methods of procedure in this investigation.

In order to do entire justice to the various types of units under consideration, also to avoid disturbing the wares and stocks of the building owners who so kindly granted permission to perform the work, the location of the test area or bay was in every case chosen without reference to the condition of the light sources, except to note that every outlet within the effective range of the test bay contained no burnouts.

Each bay, or area enclosed by the columns in which there was the unit number of lamps, was divided into a great number of equal small areas, and the illumination determined in

TABLE I

Location	Test Number	Approximate Service Between Cleaning Weeks	Type of Lamp	Type of Glassware	Number Lamps per Bay	Mean Illumination System Clean	Mean Illumination System Dirty	Illumination Per cent. Increase	Illumination Per cent. Loss
P. & L. E. R. R., Pittsburgh	1	30	187-watt B. F. Gem	Clear Holophane D-4	2	2.14	1.73	23.8	19.23
The Hub, Chicago	2	2	0.4-amp. Enclosed Arc	12-inch Oval Alabaster Ball	1	3.01	2.41	24.9	19.94
Xerxa, Minneapolis	3	4	Tungsten Economy Diffuser No. 60,288	Opalescent Sand Blast Inside 24-inch Shade	5 (100-watt)	6.27	5.73	9.42	8.67

 *N. E. L. A., 1909.

TABLE II

Location	Test Number	Approximate Service Between Cleaning Weeks	Type of Lamp, Tungsten	Glassware, Clear Holophane	Number of Lamps per Bay	Mean Illumination System Clean	Mean Illumination System Dirty	Illumination Per Cent. Increase	Illumination Per Cent. Loss
Gimbel Bros.,	4	8	60 watt B. Frost	No. 6061	4*	1.83	1.49	22.8	18.6
Milwaukee	5	8	60 watt B. Frost	No. 6061	4*	2.65	2.16	22.68	18.5
Block Bros.,	6	15	60 watt B. Frost	No. 6061	6†	3.08	2.76	11.59	10.4
St. Joseph	7	15	60 watt B. Frost	No. 6061	6†	2.46	1.83	34.4	25.6
Mulford's, St. Louis	8	8	40 watt B. Frost	No. 7381	4*	3.13	2.35	33.2	24.9
Cap Gassar, Duluth	9	3	60 watt B. Frost	No. 6061	5*	3.10	2.84	9.15	8.40
P. & L. E. R. R., Pittsburgh	10	25	100 watt B. Frost	No. 6080	4†	7.95	5.67	40.2	28.7
Fifth Ward School, N. S. Pgh.	11	4	100 watt B. Frost	No. 6061	2*	2.19	1.93	13.54	11.93
Derby Desk Co., Pittsburgh	12	30	60 watt Clear	Ho. 6060	4*	4.45	2.73	63	38.9

*Clusters. †Distributed System.

NOTE.—In test No. 6 one row only was cleaned.

the center of each small area, which represents the mean illumination for that area. The arithmetical means of the various values of illumination found in all small areas is, therefore, a very close approximation to the mean illumination of the bay or system. These test stations were carefully marked and a set of illumination readings obtained before and after cleaning. The cleaning was accomplished, in every case, by removing the units within effective range and carefully wiping the lamp itself with a damp cloth and scrubbing the reflectors with a brush, soap (or cleaning compound) and water, since it has been the author's experience that mere wiping of reflectors is not entirely effective in all cases.

Simultaneous voltage readings were taken with illumination, and corrections were made according to voltage-candle-power characteristics where the operating voltage was other than normal.

The equipment used in all the work was the Sharp-Millar photometer with the necessary measuring instruments, all of which were thoroughly calibrated before and after each test or trip when the laboratory was not available.

The original plans of procedure in the commercial tests included an elaborate investigation of arc systems, but later, the tests—in so far as arcs are concerned—were abandoned because of the great difficulty encountered in the unsteady illumination produced by the arc system and the uncertainty as to the cause of the difference in the figures for the system when operating clean and dirty. It will be noted that the products of combustion in the enclosed arc are of greater consequence than atmospheric dirt, and in many cases where cheap carbons are used the loss in illumination due to this cause alone is enormous after one day's service.

In view of the fact that the increase in illumination due to cleaning the system is purely relative, and the various elements that ordinarily would have great weight in tests of this character have been eliminated, so far as comparisons are concerned, the data given are confined to this subject.

The results secured on an installation of Gem lamps (Test 1) form the basis for an interesting comparison between the losses on two units (Test 10) of widely different types, in which the relatively large amount of surface exposed by the bowl-frosted lamp, when used with a D-4 reflector, is the direct source; the loss where the conditions of service and cleaning are on an equality is less by far than the unit (Test 10) that depends solely upon a reflector to re-direct the light into the useful plane; for the unit that naturally delivers the greatest flux of light in the useful direction without reflection the loss will be the total loss in the process of reflection.

An indication of the performance of the commercial enclosed arc when operated in the clean and dirty condition is given in Test 2. By reason of the fact that it was impossible to remove all of the stains on the inner globe with the cleaning facilities available at the time of the test, as well as the difficulties surrounding tests on arc illumination mentioned above, these results are, no doubt, more favorable to the arc lamp than would be found in general practice, and should be considered as indicative rather than conclusive.

The economy diffuser (Test 3), from its inherent advantage in construction, provides a smooth surface, which, although having considerable area, is so ventilated that the collection of dirt is reduced to a minimum, and has the desirable smooth surface that is easily cleaned. It is probable, however, that the losses will be proportionally greater after the unit has been in service for a considerable period of time when the rough interior surface of the glassware assumes the characteristic dark appearance.

Again, a review of the results secured on various equipments of tungsten lamps, with their auxiliary reflectors (Table II), indicates that the loss due to the accumulations of dirt and the grimy or foggy appearance of the inner surface of the reflector is an important factor. Here the mean loss in illumination in the tests given was 20.66 per cent. for a period of approximately thirteen weeks between cleaning.

The results of tests (Table III) on installations of Nernst lamps indicate the loss due to accumulations of dirt on the standard glassware used on that type of lamp. Owing to the nature of the surface of this alabaster glassware, it is obvious that but little dirt will settle on the lower half of

TABLE III

Location	Test Number	Approximate Service Between Cleaning Weeks	Type of Lamp, Nernst	Glassware, Alabaster Balls	Number of Lamps per Bay	Mean Illumination System Clean	Mean Illumination System Dirty	Illumination Per Cent. Increase	Illumination Per Cent. Loss
Armour & Co.	13	6	Old 110-watt	5-inch	4†	3.45	3.28	5.2	4.93
Marshall Field & Co.	14	3	Old 6-glower	9-inch	2†	6.68	6.58	1.52	1.50
	15	3	Old 6-glower	9-inch	2†	6.43	6.34	1.42	1.40
	16	3	Old 2-glower	9-inch	2†	3.24	3.	8.	7.4
	17	3	Old 3-glower	9-inch	2†	2.79	2.66	4.88	4.66
Siegel-Cooper & Co.	18	3	New 3-glower Westinghouse Nernst	9-inch	1	3.39	3.17	6.94	6.50
	19	3	New 3-glower Westinghouse Nernst	9-inch	1	3.18	2.85	11.6	10.4
McKelvey & Co., Youngstown, Ohio	20	12	New 3-glower Westinghouse Nernst	9-inch	1	2.99	2.88	3.8	3.68
Rosenbaum & Co., Pittsburgh, Pa.	21	4	New 3-glower Westinghouse Nernst	9-inch	1	4.34	4.20	3.3	3.23
Denton, Cuttier & Daniels, Buffalo, N. Y.	22	30	Old 110-watt Nernst	5-inch	4*	2.50	2.42	3.3	3.2

*Clusters. †Distributed System.

TABLE IV

COST OF CURRENT LOSS BY REASON OF LOSSES IN ILLUMINATION OF 10, 15, 20 AND 25 PER CENT. BASIS

150 Lamps Cleaned Once per Month, Labor at $2.00 per Day

Hours Service per Day				40-Watt Lamps				60-Watt Lamps				100-Watt Lamps			
4	3	2	1												
Cost of Current per Kw.				10%	15%	20%	25%	10%	15%	20%	25%	10%	15%	20%	25%
			$0.01	$0.156	$0.234	$0.312	$0.39	$0.234	$0.351	$0.468	$0.585	$0.39	$0.585	$0.78	$0.975
		$0.01	0.02	0.312	0.468	0.624	0.78	0.468	0.702	0.936	1.17	0.78	1.17	1.56	1.95
	$0.01		0.03	0.468	0.702	0.936	1.17	0.702	1.053	1.404	1.755	1.17	1.755	2.34	2.925
$0.01		0.02	0.04	0.624	0.936	1.248	1.56	0.936	1.404	1.872	2.34	1.56	2.34	3.12	3.90
			0.05	0.780	1.170	1.560	1.95	1.17	1.755	2.34	2.925	1.95	2.925	3.90	4.875
	0.02	0.03	0.06	0.936	1.404	1.872	2.34	1.404	2.106	2.808	3.51	2.34	3.51	4.68	5.85
			0.07	1.092	1.638	2.184	2.73	1.638	2.457	3.276	4.095	2.73	4.095	5.46	6.825
0.02		0.04	0.08	1.248	1.872	2.496	3.12	1.872	2.808	3.744	4.68	3.12	4.68	6.24	7.80
	0.03		0.09	1.404	2.106	2.808	3.51	2.106	3.159	4.212	5.265	3.51	5.265	7.02	8.775
		0.05	0.10	1.56	2.34	3.12	3.90	2.34	3.51	4.68	5.85	3.90	5.85	7.80	9.75
			0.11	1.716	2.574	3.432	4.29	2.574	3.861	5.148	6.435	4.29	6.435	8.58	10.725
0.03	0.04	0.06	0.12	1.872	2.808	3.744	4.68	2.808	4.212	5.616	7.02	4.68	7.02	9.36	11.70
			0.13	2.028	3.042	4.056	5.07	3.042	4.563	6.084	7.605	5.07	7.605	10.14	12.675
		0.07	0.14	2.184	3.276	4.368	5.46	3.276	4.914	6.552	8.19	5.46	8.19	10.92	13.65

the ball—the part that the greater portion of the effective flux of light penetrates; and, further, that the very smooth surface of the ball permits of rapid cleaning. Experience has demonstrated that a damp cloth will effectively clean this smooth type of glassware. Under normal conditions of maintenance the charge for labor in both repairing and cleaning such a system has, for a period of several years, been estimated at two mills per kilowatt-hour for the average installation when provided with a periodic and systematic maintenance. The amount of this cost charged to labor for cleaning is very reasonable, as indicated by the summary of the several tests on existing installations which show a mean, in all tests, of 4.68 per cent. loss in illumination for an average period of seven weeks' service. The cause for the difference in the amount of light lost between the type of unit that employs a reflector and the unit that employs no reflector is obvious when it is borne in mind that the reflector becomes a part of the source.

The maintenance problem of any lighting system, so far as labor for cleaning glassware is concerned, resolves itself into a comparison between the relative cost per kilowatt-hour for the cleaning of any individual installation and the cost of current lost by reason of the decreased efficiency due to dirty and unclean glassware.

Experience and investigation indicate that the average trimmer can remove and thoroughly clean, by scrubbing, 150 units (lamp and prismatic reflectors) per day, where the nature of the floor space is such that only moderate care must be exercised in moving the ladder or means of reaching the various lamps; and with this as a basis the figures in Table IV are derived.

The question of the amount of justifiable labor to maintain a minimum loss under normal operating conditions is one open to considerable discussion and can be determined only after taking into consideration the details of each individual installation, such as cost of current, efficiency of labor, and the like. One method of determining the justifiable cost of labor is given in Table IV, in which will be seen the costs of current for given losses beyond which it would certainly be cheaper to clean the lamps in order to maintain the mean illumination up to a certain standard.

In the opinion of the author, the figures indicate that in the case of systems employing prismatic glassware a gain of 10 per cent. in mean illumination can be obtained if such systems are inspected and cleaned once per month.

Such a gain is equivalent to an increased consumption of 10 per cent. in current to obtain equal illumination where such systems are not cleaned once per month, so that in the case of installations that are operated one hundred hours per month the cost of current per kilowatt-hour would have to be lower than the figures herewith given, not to justify cleaning once per month as recommended: In the case of 100-watt lamps, 1.33 cents per kw-hr.; in the case of 60-watt lamps, 2.25 cents per kw-hr., and in the case of 40-watt lamps, 3.25 cents per kw-hr. When the additional renewals are considered, in case the fixed mean illumination is maintained by increasing the initial current consumption, the above figures would point even more to the economy by cleaning.

The relation of the deterioration of a system of illumination due to the dirty condition of the glass ware, the working efficiency, or average illuminating results, to the cost of maintenance is surely a question of great importance; and when the time is ripe to buy illumination on the basis of illumination actually produced (as has already been done in a few important cases) the problem of a fair and reasonable maintenance depreciation value will be as important as the depreciation in actual candle-power of the lamp itself.

The author regrets inability to include information on this subject secured on various forms of commercial reflecting devices, such as opal, opalux, satin finish, *et cetera*, recently placed on the market, due to the inaccessibility of installation of the same for test purposes.

While the above figures were based on cleaning every month, it will be noted that all tests were made in buildings of a generally clean character (merchandizing and office) and in many classes of work, it would, doubtless, be advisable to provide a thorough cleaning once in two weeks, in such places as our great industrial establishments, foundries, machine shops, planing mills, textile mills, and the like, where the efficiency of production depends directly upon the efficiency of the lighting system.

Meters

Induction Type Wattmeters

BURLEIGH CURRIER

Electrolytic meters are designed for use on direct-current circuits only.

A representative type of the modern electrolytic meter is the Bastian meter, shown in Fig. 35. This is an ampere-hour meter, but the manufacturer calibrates the scale directly in watt or kilowatt-hours by assuming a standard voltage.

The tube contains water, to which caustic soda is added in order to lower the resistance of the solution and prevent freezing, and a thin layer of highly-colored oil is floated on top of the solution to prevent evaporation and to facilitate reading.

The following abbreviations refer to Fig. 35, which shows the essential parts of the Bastian meter:

C and C^1 = current cables
CT and CT^1 = current terminals
E and E^1 = iron electrodes
GT = glass tube
LC = lead cap, to prevent moisture from escaping with gas
LS = lead plug, to permit filling
R and R^1 = current leading-in conductors
S and S^1 = graduated scale

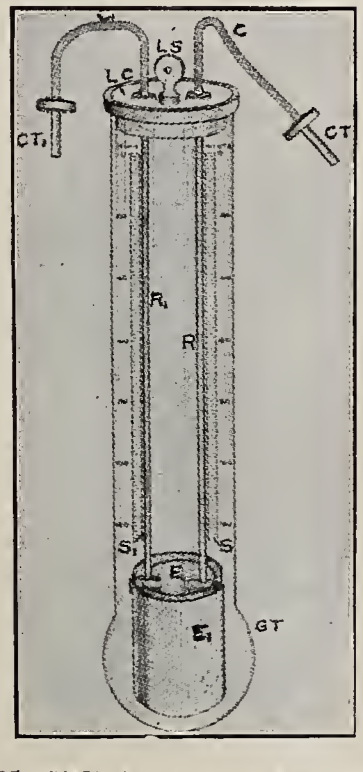


Fig. 35—HELIOS, BASTIAN ELECTROLYTIC METER

GENERAL INFORMATION

Dial Gearing.—As previously stated, to register properly the current or energy consumed it is necessary to register the number of revolutions of the moving element. To accomplish this the moving element is arranged to drive a registering mechanism or dial register.

It is desirable to have the dials indicate in commercial units, and as each revolution generally represents but a very small fraction of a unit it is necessary to employ a train of gears to obtain the proper speed at the register.

The relative speed of a driven to a driving gear depends upon the ratio of the number of teeth.

In Fig. 36 is shown the gear A with 30 teeth driving the gear B having 15 teeth, and the gear C with 30 teeth driving the gear D having 10 teeth, therefore

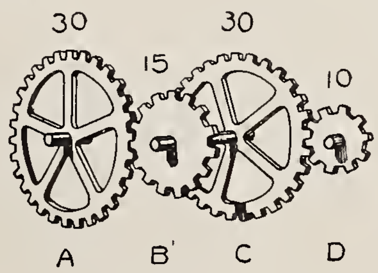


Fig. 36—SIMPLE GEARING

1 revolution of $A = \frac{30}{15}$ or 2 revolutions of B, and

1 revolution of $C = \frac{30}{10}$ or 3 revolutions of D

As B and C are mounted on the same shaft, they will necessarily have the same speed, and one revolution of A will produce 6 revolutions of D.

This relation may be expressed thus:

$$\frac{A \times C}{B \times D} = \text{Revs. of } D \text{ to one of } A$$

or

$$\frac{30 \times 30}{15 \times 10} = 6 \text{ Revs. of } D \text{ to one of } A,$$

resulting in an increase in speed.

When the gear D drives C, and B drives A, the relation may be expressed as follows:

$$\frac{D \times B}{C \times A} = \text{Revs. of } A \text{ to one of } D$$

or

$$\frac{10 \times 15}{30 \times 30} = \text{One-sixth revolutions}$$

of A to one of D, resulting in a reduction of speed.

In the dial gearing of meter registers, a reduction of speed is desirable so that the method of calculation given may be employed to determine the speed of a train of gears having any number of gear wheels. The arrangement of gears shown represents the general method employed in meters to reduce the speed of the dial register.

A worm and worm wheel are frequently used in connection with gears for speed reduction.

A single worm is simply a screw thread on a shaft and in a train of gears acts similarly to a gear having but one tooth. Usually the worm is arranged so as to engage a worm wheel or gear having a correspondingly large number of teeth. A double worm is sometimes employed, consisting of two screw threads on a shaft, which acts as a gear with two teeth.

In calculations a single worm should be considered as a gear having one tooth and a double worm as a gear having two teeth.

A worm or gear mounted on the shaft of the moving element is generally used to drive the gear train which actuates the dial hands.

Various arrangements of gears and worms are employed to produce practically the same results, several of which are shown in Figs. 37, 38, 39 and 40.

In Fig. 37 K represents an idler wheel, which is two gears on a common shaft, each having the same number of teeth. The idler does not change the speed, but is used to reverse the direction of the dial hand.

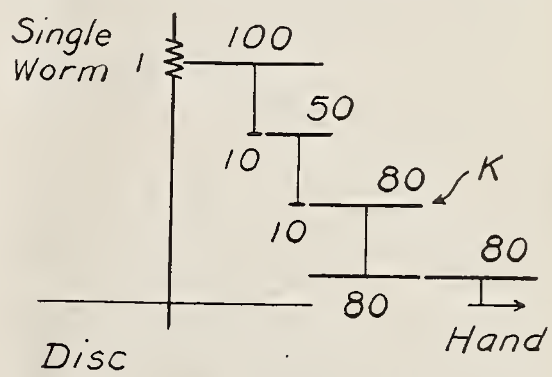


Fig. 37—DIAL GEARING WITH WORM ON ARMATURE SHAFT

In Fig. 38 a gear on the shaft connects the moving element to the train, and a double worm is used, as indicated by L.

In Fig. 39 two single worms are used, to reduce the number of gears necessary to obtain the desired speed.

Calculation of Dial Gearing and Test Constant.—It is sometimes desirable to ascertain the number of rev-

NOTE—Continued from August issue and concluding article begun in July.

olutions of the moving element required to make a complete revolution of the first dial hand. When the number of teeth in each gear wheel has been determined, a convenient method of arranging the gears to facilitate calculation is shown in Fig. 40, and the example shows the calculation necessary.

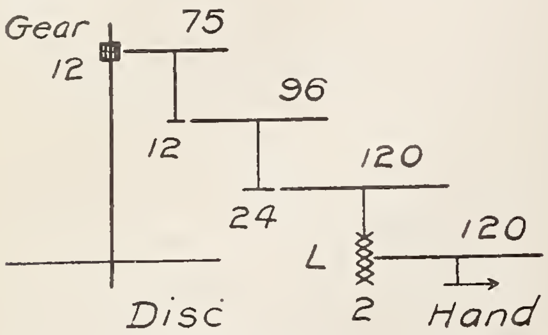


Fig. 38—DIAL GEARING WITH PINION ON ARMATURE SHAFT

Example:

$$\frac{100\times48\times36\times40\times120}{1\times12\times12\times12\times12} = 40{,}000$$

revolutions of the moving element necessary to produce one complete revolution of the first dial hand.

Arrange the figures representing the number of teeth in the gear wheels according to their relative position in the gear train, as shown in the diagram, and draw the diagonal line *AA*. It will be noted that the number of teeth in the driven gears are above the diagonal line and the number of teeth in the driving gears are all below the line. When the product of the numbers above the line is divided by the product of the numbers below the line, the result will be

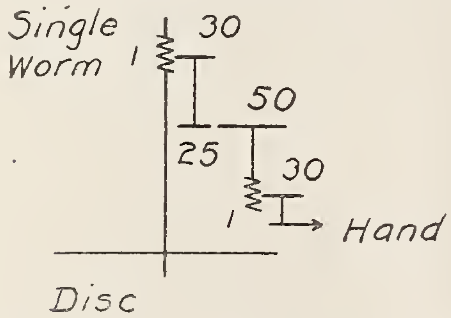


Fig. 39—DIAL GEARING WITH TWO WORMS

the gear ratio or the number of revolutions of the moving element required to make a complete revolution of the first dial hand.

When the total number of watt-seconds registered by one revolution of the first dial hand is divided by the number of revolutions of the moving element necessary to produce one complete revolution of the first hand, the result will represent the value on the dial of one revolution of the moving element in watt-seconds, which is the test constant used in the universal formula

$$\frac{\text{Watt-seconds}\times\text{revolutions}}{\text{Seconds}} = \text{meter}$$

watts. By dividing the watt-seconds per revolution of the moving element by 3600, the value of one revolution in watt-hours may be obtained, which is the constant used in the formula

$$\frac{3600\times\text{revolutions}\times\text{constant}}{\text{Seconds}} = \text{meter}$$

watts.

LABORATORY TESTS

The following tests are generally considered necessary in order to determine the characteristics of any particular make or type of meter.

The instruments used should be thoroughly reliable and in perfect calibration.

All tests should be made at the normal rated voltage of the meter unless otherwise specified.

Curves should be plotted of each test, and these, together with all information, should be carefully filed for reference.

While the tests as herein outlined usually cover only single conditions, yet in service meters are subjected to conditions that will require a combination of some of these tests; as for instance, when the meter is subjected to both excessive voltage and low power factor.

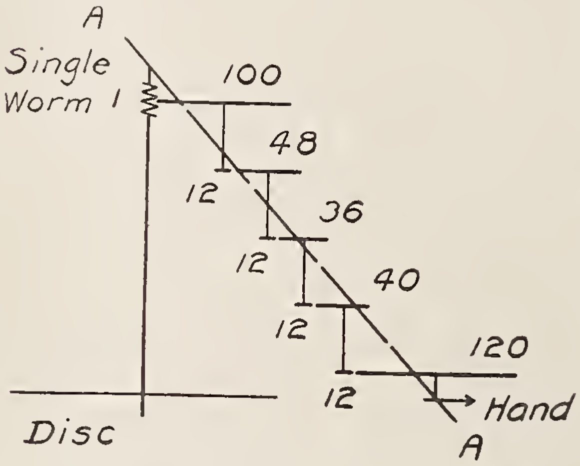


Fig. 40—METHOD OF OBTAINING GEAR RATIO

Test 1.—Determine the accuracy of the meter as received, on loads of 5 per cent. and 100 per cent. of the normal rated capacity in amperes. This will indicate if the accuracy of the meter has been affected by transportation. A thorough examination of the parts should also be made. If the meter is designed for alternating-current circuits, determine the accuracy on a 50-per cent. non-inductive load and on a 50-per cent. inductive load having a 50-per cent. power factor.

Test 2.—Calibrate the meter on 5-per cent. and 100-per cent. loads, and if of an induction type on a 50-per cent. inductive load having a 50-per cent. power factor, a balance should be obtained on loads of the same true wattage. The meter will then be in proper calibration for further tests.

Test 3.—Determine the accuracy on 2, 5, 10, 25, 50, 75, 100, 125, 150 and 200-per cent. loads.

This will give data for a general accuracy curve, which should be plotted with true watts on the horizontal and percent accuracy vertically.

Test 4.—Make a series of accuracy tests on 2, 5 and 10-per cent. loads in order to determine the stability of the light-load accuracy and to ascertain if the friction is constant or variable.

Test 5.—Determine the smallest load which will produce a complete revolution of the moving element, and ascertain the percentage accuracy on this load.

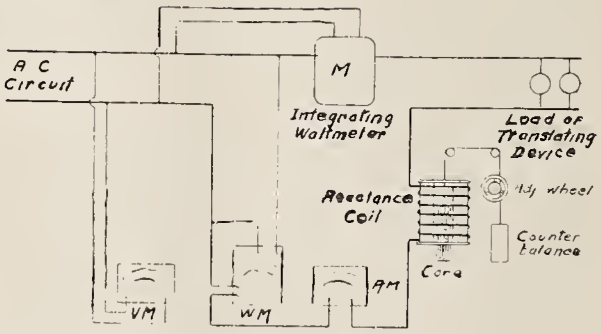


Fig. 41—IMPEDANCE-COIL METHOD OF VARYING POWER FACTOR

Test 6.—Determine the overload capacity by gradually increasing the overload until the meter is liable to damage, or until its error reaches the limit of commercial accuracy. In either case the limit of the overload capacity of the meter will have been reached, and these results should be determined separately. Subsequent friction or deterioration of the parts due to high speed on overloads should also be considered.

Test 7.—Test the meter on 5-per cent. and 100-per cent. loads with the cover on, and then with the cover off. If there is an appreciable difference in the results, readings should be taken on other loads.

When the accuracy of the meter differs greatly with the cover on and off, an error will result when the meter is calibrated in service with the cover off, and to test such a meter properly would be cumbersome.

Test 8.—If the meter under test is designed for alternating current, conduct tests on inductive and non-inductive loads of the same true wattage. The power factor should be from 50 to 70 per cent.; a 50-per cent. power factor is preferable, as errors are more easily detected. This test will indicate the accuracy of the meter when registering on inductive loads of varying power factor, which is a condition of motor circuits.

Test 9.—Determine the accuracy of the meter on a 25-per cent. increase and a 25-per cent. decrease in voltage.

First, increase the voltage 25 per cent. above the normal rated voltage and ascertain the accuracy on 5, 10, 25, 50, 75 and 100-per cent. loads. Second, decrease the voltage 25 per cent. below normal and ascertain the accuracy on the same loads.

The voltage of the circuit on which a meter is installed may not be the same as its voltage rating, and the circuit voltage may not always be the same at all times, hence these tests are desirable.

Test 10.—Ascertain if the meter will creep.

This should be determined under conditions of no vibration, and of vibration that may be artificially produced.

The meter being in proper calibration, connect the potential circuit only and make observations, as stated. First on normal voltage, second on 125 per cent. of normal voltage and third on 75 per cent. of normal voltage. The voltage should be gradually increased and decreased until the 25-per cent. limit is reached.

The extent that the accuracy of the meter can be increased at 5-per cent. capacity without producing creep on no load should also be determined. A meter is not considered as creeping unless the moving element makes complete revolutions, as a partial revolution may result from an electrical or mechanical unbalanced condition.

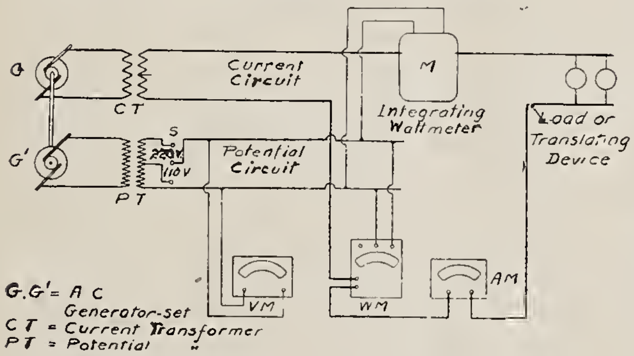


Fig. 42—TWO-GENERATOR METHOD OF CHANGING POWER FACTOR FOR TESTING

Test 11.—Ascertain the accuracy of the meter on circuits where the current or voltage is rapidly changing or fluctuating. Also note the operation of the meter under these conditions.

The most practical method of determining this is to install the several types of meters under test on the same circuit.

The current coils of the meter should be connected in series, and the potential leads should be connected to the circuit at the same point and ahead of all the current coils. If a potential wire is connected to the current coil in the meter it must be disconnected and an independent potential wire connected to the circuit, as stated. By this arrangement none of the meters will register the current consumed by the potential circuit of any of the other meters. A comparison may then be made between the amount of the registration as indicated by the dials of the different meters.

Conditions for the test may be produced by connecting a sign flasher or similar device in circuit. When the load is known and constant, the apparatus may be timed, and interesting information and data may thus be obtained.

Test 12.—Determine the accuracy of the meter when operating on alternating currents having different wave forms.

Special laboratory generators are designed which will produce currents having also any desired wave form, but, when such a generator is not available, a simple test may be conducted by supplying the meter with current from circuits on different transformers or different alternators. Determine the accuracy under the above conditions on 5, 10, 25, 50 and 100-per cent. loads and compare these tests with the accuracy tests under normal conditions.

Test 13.—Determine the effect on the meter accuracy of 2 to 5-per cent. variations in frequency.

Slight changes in frequency may be produced by changing the speed of the alternator supplying current to the meter under test. Circuits of different frequency may also be available for these tests.

Conduct tests under the condition stated at normal rated voltage on 5, 10, 25, 50 and 100-per cent. loads.

Changes in frequency may occur when circuits are changed from one generator to another or where the speed of the generator is affected by changes of load, consequently a meter should maintain its accuracy under reasonable variations of this character.

Test 14.—Determine the effects of full-load adjustment.

The meter should first be in accurate calibration, then alter the full-load adjustment until the accuracy is

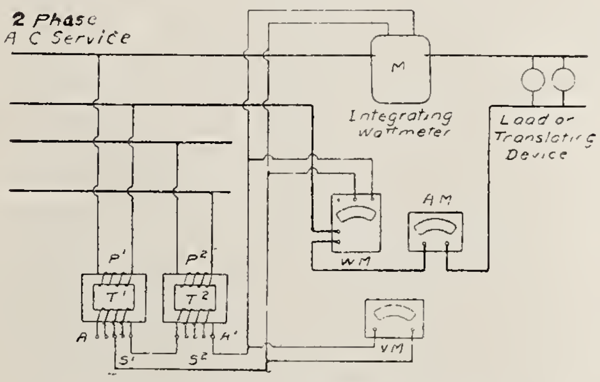


Fig. 43—TWO-TRANSFORMER METHOD OF OBTAINING DIFFERENT POWER FACTORS

110 per cent. on 100-per cent. load. Conduct tests under these conditions on 2, 5, 10, 25, 50 and 100-per cent. loads. Similar tests should be conducted after adjusting the meter at 90-per cent. accuracy on 100-per cent. load. This will show the effect on the accuracy of the meter at each of the above percentage loads.

The full-load adjustment in most modern meters is effected by the drag magnets.

Test 15.—Determine the range of full-load adjustment.

The meter should first be in accurate calibration, then move the adjustment to its maximum and then to its minimum position and take accuracy readings under each condition on 5-per cent. and 100-per cent. loads.

Test 16.—Determine the effect of the light-load adjustment on the meter accuracy.

The meter should first be in accurate calibration, then alter the light-load adjustment until the accuracy is increased 10 per cent., if possible, on a 5-per cent. load.

Accuracy tests should be conducted under this condition on 2, 5, 10, 25, 50, and 100-per cent. loads. Similar tests should be conducted with the 5-per cent. load accuracy decreased 10 per cent. These tests will indicate the extent that the meter accuracy is affected by the light-load adjustment.

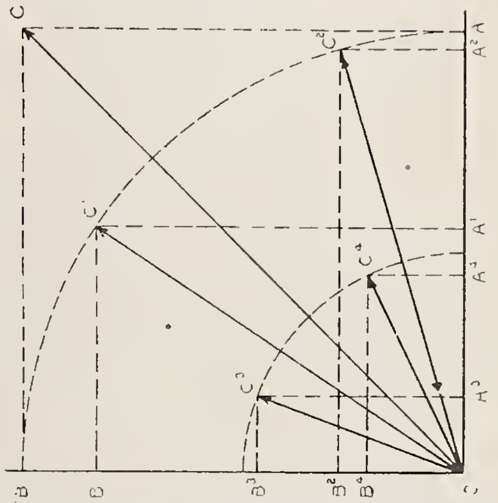


Fig. 44—VECTORS FOR TWO-TRANSFORMER METHOD OF PRODUCING POWER FACTORS ON A TWO-PHASE CIRCUIT

Test 17.—Ascertain the range of the light-load adjustment.

The meter should first be in accurate calibration, then move the adjusting device to the maximum position and then to the minimum position of adjustment.

Conduct accuracy tests under each condition on 2, 5, 10, 25, 50 and 100-per cent. loads.

Test 18.—Determine if an adjustment of the light-load adjusting device alters the calibration of the meter on inductive loads.

The meter should first be in accurate calibration, then move the light-load adjustment until the 5-per cent. load accuracy is increased 10 per cent.

Tests should be conducted on inductive loads having a 50-per cent. power factor at the 2, 5, 10, 25, 50 and 100-per cent. load points. Similar tests should be conducted with the 5-per cent. load accuracy decreased 10 per cent.

If the meter is affected by this adjustment it is not suitable for alternating-current power installations.

Test 19.—Determine the effect that

changing the inductive load adjustment has on the non-inductive load accuracy.

The meter should first be in accurate calibration, then change the inductive load calibration 3 per cent. on a 50-per cent. load having a 50-per cent. power factor.

Conduct tests on 2, 5, 10, 25, 50 and 100-per cent. loads.

These tests will show the effect on the accuracy of the meter of changing the inductive load adjustment. When the non-inductive load is appreciably affected the balancing of the meter on inductive load is more difficult.

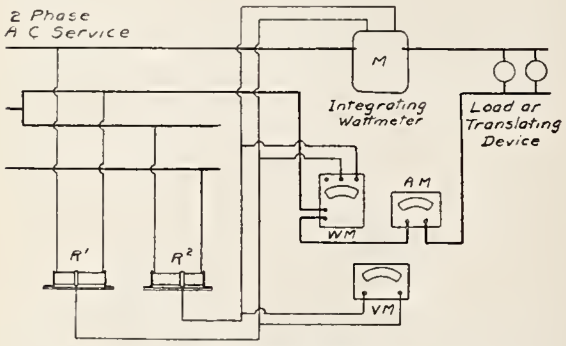


Fig. 45—TWO-PHASE RESISTANCE METHOD OF VARYING POWER FACTOR

Test 20.—Determine the effect of magnetic fields on the meter accuracy.

Calibrate the meter in a position where there is no possibility of the existence of an external magnetic field.

Arrange a bus bar or conductor, carrying a current equal to twice the ampere capacity of the meter in various positions in proximity to the meter, and determine the acuracy under the different conditions.

Conduct tests on 2, 5, 10, 25, 50 and 100-per cent. loads.

This test will determine the distance the meter should be installed from conductors carrying large currents.

Test 21.—Determine the minimum distance which should be maintained between the centres of meters when installed in service.

Two meters should be accurately

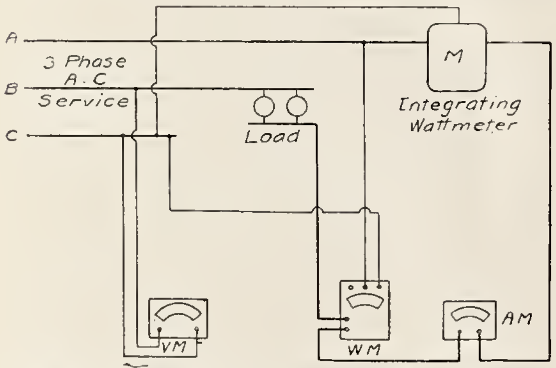


Fig. 46—THREE-PHASE METHOD FOR OBTAINING 50 PER CENT. POWER FACTOR

calibrated, in position, on 5-per cent. and 100-per cent. loads. Each meter should be calibrated separately when there is no load on the other meter.

One meter should be operating constantly on a 100-per cent. load, while the accuracy of the other meter is determined with various distances between the centres of the two meters. When varying the distance between the two meters, the meter having the constant load should be moved and never the meter being tested.

Test 22.—Determine the accuracy of the meter when operating under conditions of different temperatures.

Some laboratories have rooms or compartments that are equipped with the necessary apparatus and thermostats to produce and maintain any desired temperature. Tests are made on the meter at various temperatures and the effect on its accuracy determined on 5, 10, 25, 50 and 100-per cent. loads.

Test 23.—Determine the torque or turning effort.

The torque of the meter can be measured with a suitable torque balance. The meter should be accurately calibrated, on 5-per cent. and 100-per cent. loads, and to determine the torque maintain full normal load on the meter and measure the turning effort with the balance. The torque should be expressed in millimeter grammes.

Test 24.—Determine the weight of the rotating parts.

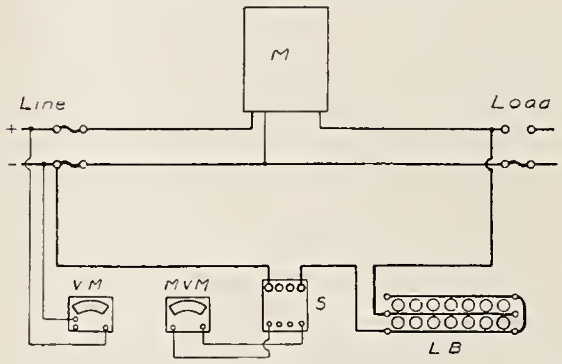


Fig. 47—TESTING LOW-CAPACITY, 100-VOLT, DIRECT-CURRENT METERS

In order to weigh the rotating element, use chemical or physical laboratory scales and accurately determine the weight in grammes. It is preferable to weigh several elements and obtain the average weight, as the weight of the parts may vary slightly, due to the slight difference in construction and to the balancing of the element when assembled by the manufacturer. The determination of the weight of the rotating element is important, as the weight practically represents the bearing friction. The ratio between the torque and weight of the rotating element is important.

Test 25.—Determine the losses in the potential circuit.

Determine these losses, select a number of meters having the same rated voltage and connect the potential circuits in parallel. If the meters are for direct-current circuits, measure the total current and the voltage applied to the circuit, the product being the total wattage loss, which divided by the number of meters gives the wattage loss per meter.

When the meters are for alternating-current circuits, a low-range indicating wattmeter may be used, which will indicate the wattage direct. The potential circuits of a sufficient number of meters to give an adequate indication should be measured simultaneously and an average taken as the loss per meter.

It is also advisable to place a suitable ammeter in circuit, in order to de-

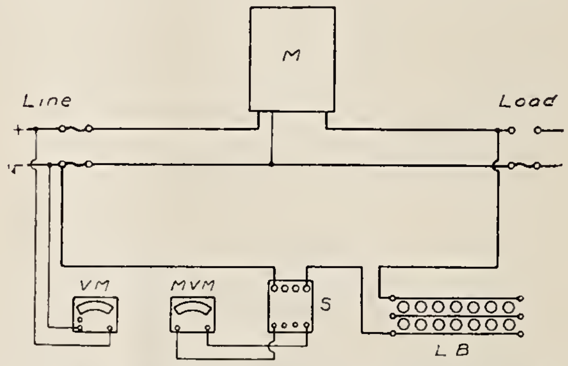


Fig. 48—TESTING SMALL-CAPACITY, 2-WIRE, DIRECT-CURRENT, 200-VOLT METERS

termine the current in the potential circuits of induction meters, since the current is the determining factor of the torque.

Test 26.—Determine the loss due to the current coils.

The loss in the series or current coils may be more accurately calculated than measured, on account of the small drop in potential which occurs. The rated current capacity of the meter being known, the full-load loss in the current coils may be calculated by the simple formula $C^2R =$ watts loss. The resistance can be readily measured with an accurate bridge.

Tests 27.—Determine the loss of auxiliary apparatus used in connection with the meters such as transformers, shunts, and the like.

If auxiliary apparatus is used, such as series and potention transformers, the wattage loss may be measured by a standard indicating wattmeter of suitable capacity and range. If a shunt is employed, as is the case in some direct-current meters, the loss may be best determined by the formula $C \times E =$ watts loss. E may be determined by taking the drop with a multivoltmeter of suitable range.

Test 28.—Method of determining the full-load speed.

To determine the revolutions per minute of a meter on full load, the product of the rated voltage and amperes capacity multiplied by 60 seconds should be divided by the value of one revolution in watt-seconds, that is,

$$\text{Rev. per min.} = \frac{60 \times M\,W}{C}$$

60 = Number of seconds in a minute
MW = Full-load capacity of meter (amperes × volts)
C = Watt-seconds registered for one revolution of the disc

The full-load speed may also be determined by timing the moving element for a definite number of revolutions, when the normal rated voltage and current is applied.

Test 29.—Conduct tests to determine the effect of possible troubles that might develop, and ascertain the best methods of readily detecting them. These troubles should be artificially produced for experimental purposes, and tests should be conducted under the different conditions to determine the action of the meter and the effect on its accuracy.

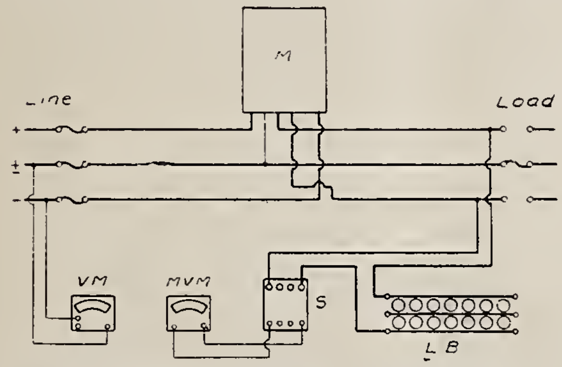


Fig. 49—TESTING 200-VOLT, 3-WIRE, SMALL-CAPACITY, DIRECT-CURRENT METERS. FIELD COILS CONNECTED STANDARD

Some of the troubles are: Open circuits in armature coils, armature leads, phasing coils, resistance coils, field coils and potential circuits; short-circuits in the field coils, armature coils, phasing coils, resistance coils, friction compensating coils, impedance coils, shunt field coils and other auxiliary windings; reversed connections of various coils, as field coils, phasing coils, compensating coils and armature sections; armatures shifted on the shaft and short-circuits in the commutator.

It is evident that other electrical and mechanical troubles may be produced, and the action of the meter when operating under these different conditions should be determined.

Test 30.—Determine the effect of friction.

To determine the effects of friction, which may exist or which are apt to develop, it is advisable to artificially produce the conditions which might occur and conduct tests to determine the effects on the meter accuracy.

To determine the effect of rough or damaged jewels, the meter should first be calibrated on a perfect jewel and then a damaged jewel substituted. Conduct tests on 2, 5, 10, 25, 50 and 100-per cent. loads, and a comparison between the former and latter tests will indicate the effect of the rough jewel on the meter accuracy.

Tests should also be conducted to determine the maximum effect of brush tension, and any other friction tests should be conducted, as the results of such tests are of value when considering the effects of possible subsequent friction.

Test 31.—Determine the accuracy of 3-wire meters when operating on an unbalanced circuit.

Connect the current coils in series and connect the potential wires to the circuit in the standard manner. Calibrate the meter on 5-per cent. and 100-per cent. loads and then conduct accuracy tests with 0, 5, 10, 25, 50 and 100-per cent. loads on coil No. 1, with no current in coil No. 2. The tests should then be repeated with each of the following loads on coil No. 2: 5, 10, 25, 50 and 100 per cent. of its capacity.

This will show how the meter operates under all conditions of unbalanced load.

Test 32.—Determine the accuracy of a multiphase meter when operating on an unbalanced load. To calibrate the meter accurately, connect the potential circuits to their respective phases. Load each motor separately and make the necessary adjustment on 100-per cent. load on one motor with the magnets. A balance must then be obtained between the accuracy of the two motors, calibrating each separately to the proper accuracy. Conduct accuracy tests on 2, 5, 10, 25, 50 and 100-per cent. loads on each motor separately, with no load on the other motor. A series of loads of 5, 10, 25, 50 and 100 per cent. of the meter capacity should then be connected to one motor and tests made on each load with 5, 10, 25, 50 and 100-per cent. loads on the other motor.

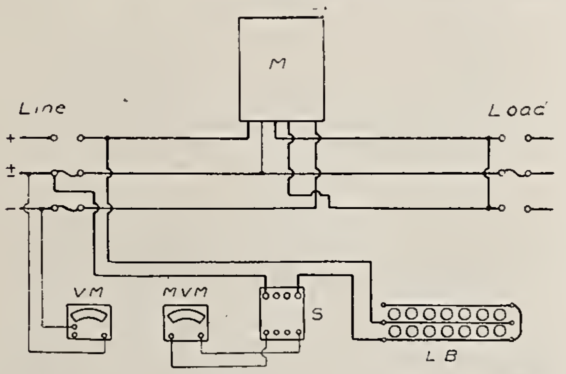


Fig. 50—TESTING 200-VOLT, 3-WIRE, DIRECT-CURRENT METERS. CURRENT COILS IN SERIES

METHODS OF OBTAINING POWER FACTORS FOR INDUCTIVE LOAD TESTS

When making adjustments on inductive loads it is necessary to provide apparatus by means of which non-inductive loads and inductive loads with constant true wattage and various power factors can be readily obtained.

As the accuracy curve of a meter taken on non-inductive loads may not be an absolutely straight line, it is important that a balance between the inductive and non-inductive load curves should be made at approximately the same true wattage.

Power factors of 25, 50 and 75 per cent. are usually sufficient to meet all requirements, but in order to check the accuracy of the registration of meters that have been running under abnormal conditions it is sometimes desirable to obtain other values.

When a multiphase circuit is available a convenient and simple method may be employed to obtain one or several power factors, so that when the load is changed the power factor of the circuit will remain constant.

This is not true of all the methods that will be considered, and the method selected should largely depend upon local conditions.

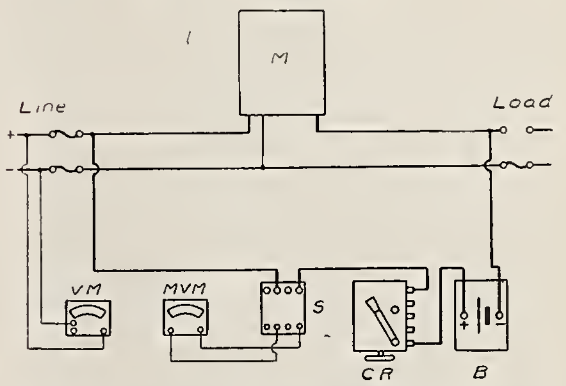


Fig. 51—TESTING LARGE-CAPACITY, 100-VOLT, DIRECT-CURRENT METERS WITH STORAGE BATTERY

Reactance Coil Method.—In the method commonly used to obtain the desired power factor, a coil with variable reactance is connected in series with the load or translating device, as shown in Fig. 41.

The power factor of the circuit is varied by adjusting the laminated-iron core in the coil by means of the adjusting wheel.

A serious objection to this method is that the power factor changes when the load is altered, making it necessary to readjust the core continually in order to obtain the same power factor for each of the loads desired.

The power factor of a circuit may be calculated from the indications of a reliable ammeter, a voltmeter and an indicating wattmeter.

An ammeter and the current coils of an indicating wattmeter are connected in series with the load or translating device, and the potential coils of the wattmeter and voltmeter are connected across the source of current.

The product of the values of current and voltage in an inductive circuit gives the apparent power in watts. The indicating wattmeter shows the true power in watts, and the ratio of the true watts to the apparent watts is the power factor of the circuit, *i. e.*,

$$\text{Power factor} = \frac{\text{True power}}{\text{Apparent power}}$$

Two-Generator Method. — Some laboratories use a specially designed generator set, which consists of two alternators coupled together and driven by the same motor.

As shown in Fig. 42, one alternator, *G*, is used for supplying the desired current at comparatively low voltage, and the other alternator, *G′*, is used for potential purposes, supplying only a limited amount of current at standard voltage.

One of the alternators is so arranged that its stator, which may be either the armature or field, can be shifted around the shaft with respect to the stator of the other alternator.

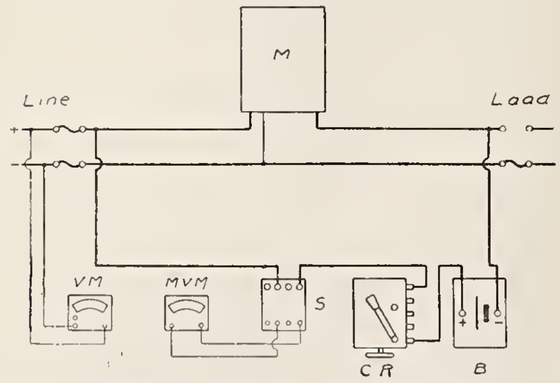


Fig. 52—TESTING LARGE-CAPACITY, 200-VOLT, 2-WIRE, DIRECT-CURRENT METERS WITH STORAGE BATTERY

When both stators are in their normal positions the currents of the two alternators will be in phase with each other.

The frequency of both alternators will always be the same, as the two rotors are rigidly coupled together.

The stator of one alternator being so arranged that it may be shifted, any desired phase relation can be obtained between the currents of the two machines.

Rheostats in circuit with the fields may be used to make the apparatus more flexible.

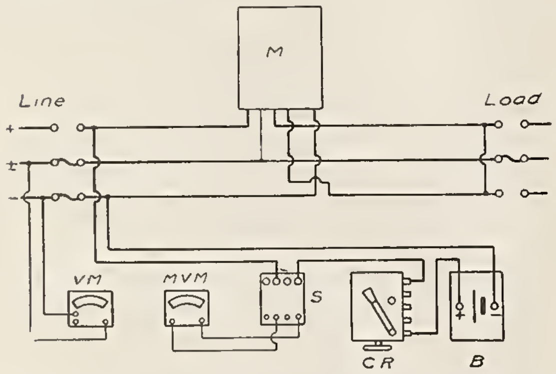


Fig. 53—TESTING LARGE-CAPACITY, 200-VOLT, 3-WIRE, DIRECT-CURRENT METERS WITH STORAGE BATTERY

It is evident that if the current or load circuit of a wattmeter is connected to one alternator and its potential circuit connected to the other alternator, any desired power factor may be obtained by adjusting the movable stator.

A scale may be made and placed in such a manner that the stator shifting device will indicate the angle of phase relation between the currents of the two alternators or the power factor without either being measured. The wattmeter only would then be necessary, the voltmeter and ammeter being used only for initial calibration of the power-factor scale.

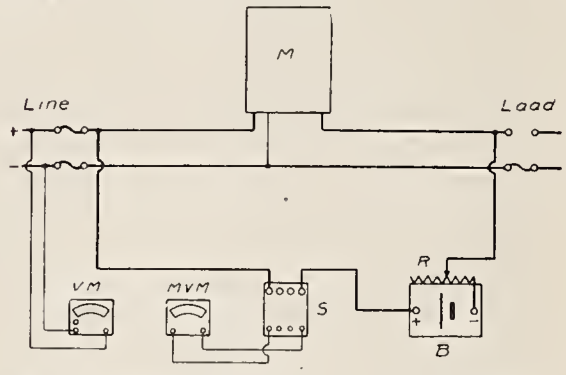


Fig. 54—TESTING 500-VOLT, 2-WIRE, DIRECT-CURRENT METERS WITH STORAGE BATTERY

Transformer Method.—For testing single-phase integrating wattmeters on inductive loads, power factors adequate to meet ordinary requirements may be obtained from the circuits of a two-phase system in the following manner:

One phase is used for the current circuit of the wattmeter under test and should have a non-inductive load, therefore the current and voltage are in phase with each other.

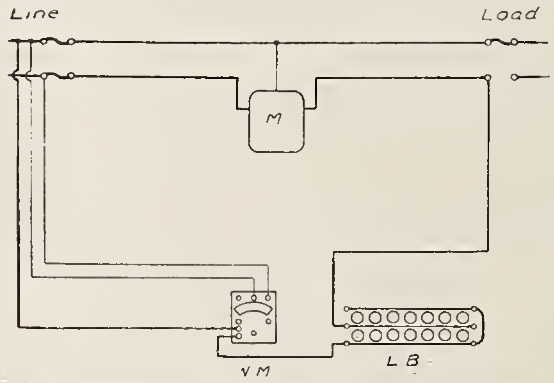


Fig. 55—TESTING SMALL-CAPACITY, 100-VOLT, ALTERNATING-CURRENT METERS

The potential current applied to the wattmeter is taken from the secondary winding of two special potential transformers, the primaries of which are connected to different phases and their secondaries connected in series.

When the transformers T^1 and T^2 (Fig. 43) are thus connected a voltage may be obtained from their secondary winding which is a resultant voltage, having a phase displacement with respect to the voltage of the current circuit. Therefore the load current will lag sufficiently behind the voltage applied to the meter to produce the same condition that exists on a single-phase circuit with an inductive load. With this method the load on the wattmeter can be varied, and the phase displacement between the current and voltage applied to the wattmeter will remain the same.

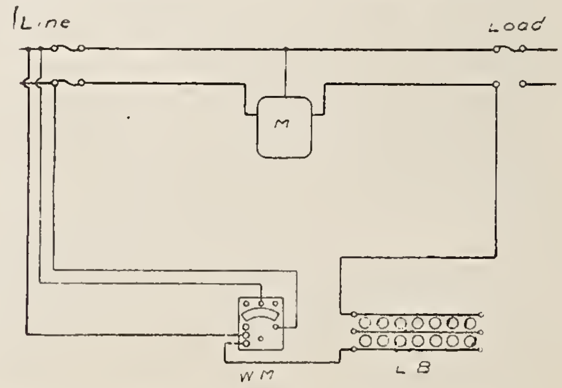


Fig. 56—TESTING SMALL-CAPACITY, 200-VOLT, 2-WIRE, ALTERNATING-CURRENT METERS

If it is desirable to obtain several different power factors, using the same potential transformers, it is evident that the transformers must have suitable taps to their secondary windings in order to give the required voltages, so that when the secondaries are connected in series a resultant voltage may be obtained that will have a value equal to the rated voltage of the meter under test with the proper phase displacement.

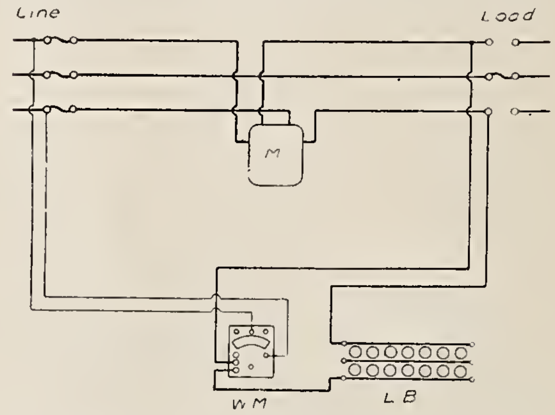


Fig. 57—TESTING SMALL-CAPACITY, 200-VOLT, 3-WIRE, ALTERNATING-CURRENT METERS. FIELD COILS CONNECTED STANDARD

The action of the transformers may be shown very plainly by a graphical construction based upon the parallelogram of forces.

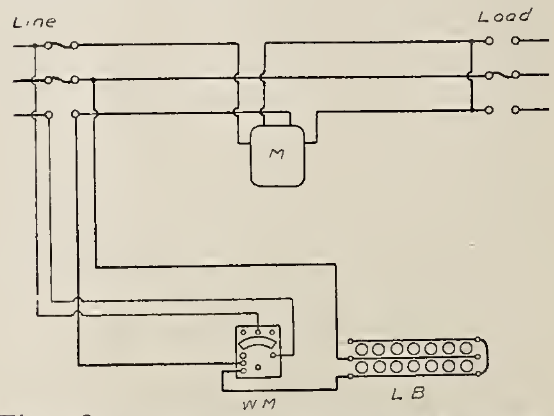


Fig. 58—TESTING 200-VOLT, 3-WIRE, ALTERNATING-CURRENT METERS, WITH FIELD COILS IN SERIES. TESTING LOAD ON 100 VOLTS

In Fig. 44 the horizontal line OA represents the full voltage of transformer T^1. This voltage is in phase with the load current. OB represents the full voltage of transformer T^2, which is 90 degrees ahead of the voltage of T^1 and equal in magnitude. The resultant voltage obtained from the two transformers connected in series is represented by OC, which

has a lead of the angle ϕ ahead of OA, and a greater length than desired. Now if the values OA' and OB' had been selected (by means of suitable taps to the secondary winding of the transformers), then the resultant of OA' and OB' would be OC', leading by the much greater angle ϕ' and having the proper length. If the values OA^2 and OB^2 had been selected instead, the resultant of these would have been OC^2, leading by a much smaller angle than in either of the previous cases. By halving the values OA and OB the system would be adapted by a meter built for half the voltages given above. The resultants are shown by OC^3, and so on. Thus, by selecting the proper values of voltages from each phase, a resultant volt-

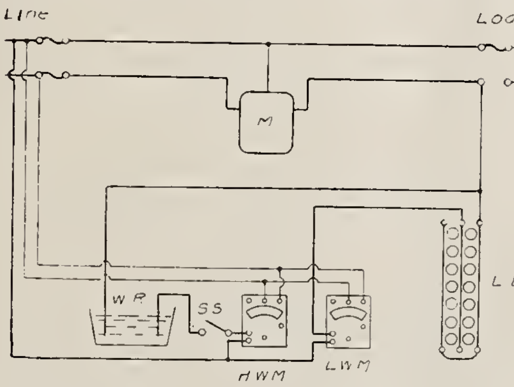


Fig. 59—TESTING LARGE-CAPACITY, 100-VOLT, 2-WIRE, ALTERNATING-CURRENT METERS, WITH WATER RHEOSTAT

age may be obtained which will have any desired magnitude and phase relation.

The transformer taps may be brought to a circular switch, the position of which will indicate the voltage and power factor under which condition the voltmeter and ammeter will be unnecessary.

A double-throw switch to give non-inductive load should be connected in the potential circuit so that the poten-

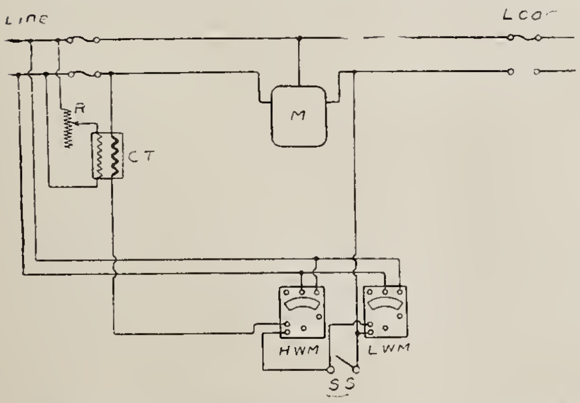


Fig. 60—TESTING LARGE-CAPACITY, 100-VOLT, 2-WIRE, ALTERNATING-CURRENT METERS, WITH INVERTED CURRENT TRANSFORMER

tial to the meter may be connected to the same phase as the current circuit.

The same principles may be applied to any multiphase system and will be found very useful, especially for laboratory and shop testing.

Resistance Method.—This method is similar to the transformer method except that two non-inductive resistances with adjustable contacts are connected across two phases, as shown in Fig. 45.

The resistances R^1 and R^2 are suitable to withstand line voltage and have a current capacity of 1 or 2 amperes.

The adjustable contacts have terminals to which are connected the potential leads of the wattmeter under test.

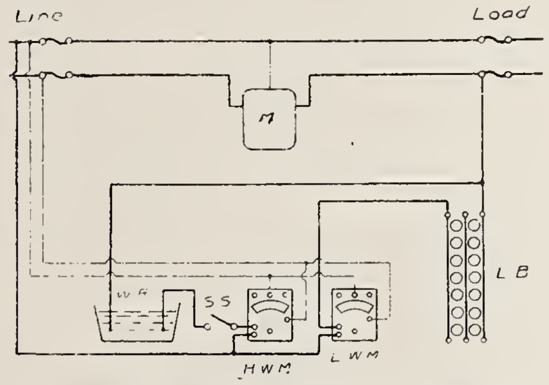


Fig. 61—TESTING LARGE-CAPACITY, 200-VOLT, 2-WIRE, ALTERNATING-CURRENT METERS

A non-inductive load is applied to the current circuit of the wattmeter in the same manner as in the transformer method.

It is evident that with this arrangement a drop of potential, with any desired phase relation with respect to the load current, may be obtained by changing the position of the adjustable contacts on the resistances.

When the proper contact points have been determined the position of the adjustable slides may be so marked

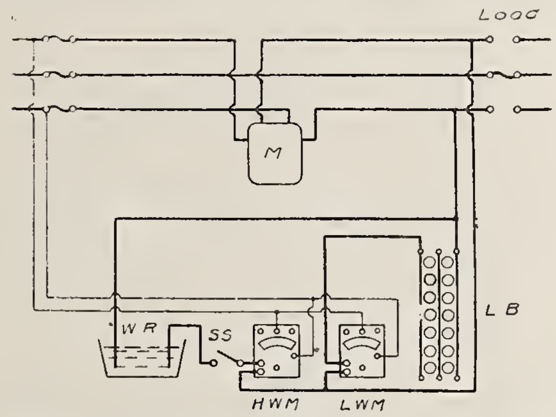


Fig. 62—TESTING LARGE-CAPACITY, 200-VOLT, 3-WIRE, ALTERNATING-CURRENT METERS, WITH THE FIELD COILS STANDARD

that approximately the same power factor can be reproduced without the voltmeter and ammeter. A double-throw potential switch should be provided and connected to the current circuit and to the resultant voltage circuit so that the voltage supplied to the meter can be taken from either circuit as desired. The voltage to produce the inductive load condition or the normal line voltage may then be conveniently and readily obtained as desired.

The apparatus for this method can be built in small portable form, which is adapted for testing meters in service at any installation where a multiphase circuit is available.

Three-Phase Method.—When testing single-phase integrating wattmeters where a three-phase circuit is available, the effect of a load with a 50-per cent. power factor is readily obtained by the connections shown in Fig. 46.

First, a single phase is taken from any two wires and a regular test on non-inductive load is made. The current circuit passes through the meter, wattmeter and load, in the order named. When the meter is adjusted properly, the potential lead is removed from the regular point to which it is connected and, with the corresponding wattmeter lead, is connected to the third wire.

On account of the 120-degree relation between the phases this gives the effect on the meter of a current with a power factor of 50 per cent.

To ascertain if the current is leading or lagging, a small impedance coil should be connected in series in the instrument potential circuit. If the instrument indicator decreases the current is lagging; if it increases the current is leading and the load should be connected across the A and C wires, and the potential leads connected to the B wire.

The voltmeter and ammeter are unnecessary in the actual test.

TESTING CONNECTIONS

The Figs. 47 to 67, inclusive, show diagrams of connections for testing meters.

The fuses not shown in these figures must always be removed in conducting a test.

When it is necessary to supply service to the consumer during a test, suitable bridging cables, equipped with fuses, should be connected ahead of the service fuses and after the house fuses, which are removed for test.

For the purpose of uniformity, indicating instruments are used as standards, but they may be replaced, if desired, by any suitable standard.

On all the tests, regular 110-volt lamps are used in the lamp banks, shown in the figures.

The secondaries of a series transformer should always be bridged be-

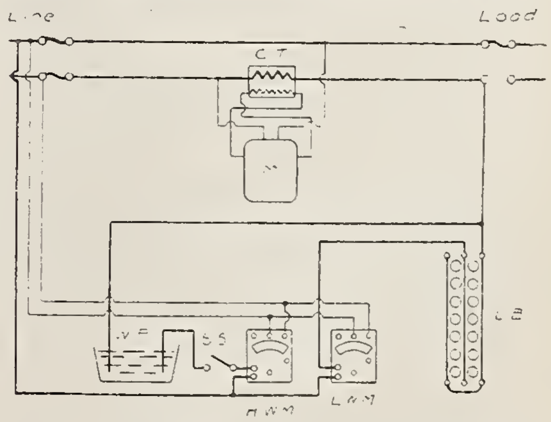


Fig. 63—TESTING 100-VOLT, ALTERNATING-CURRENT METERS INSTALLED WITH SERIES TRANSFORMERS. TESTING CONNECTIONS MADE DIRECTLY TO THE LINE

fore being disconnected from the meter, as voltage across the secondary terminals may rise dangerously high when the secondary circuit is not closed.

The secondaries of series and potential transformers should always be disconnected from the meter when it is tested as an independent meter, even though the primary circuit is dead. If this is not done before the testing connections are placed, a dangerously high voltage may be supplied by the potential transformer to feed-

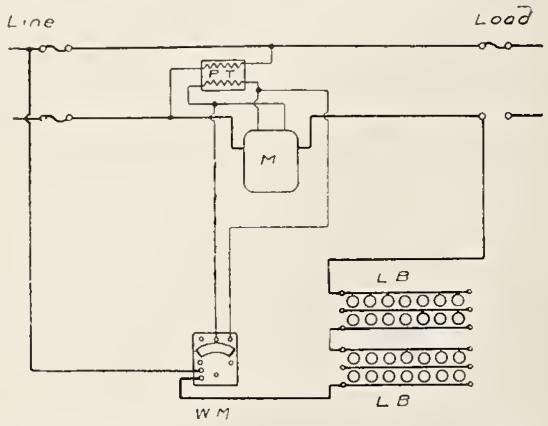


Fig. 64—TESTING 500-VOLT, 2-WIRE, ALTERNATING-CURRENT METERS, USING LAMP BANKS FOR LOAD

ers or circuits supposed to be dead and upon which work may be in progress. Any instruments or coils which are frequently installed in the secondary circuit of series transformers, in series with the meter, should remain connected in the circuit, during a test, in which the primary load is measured by the testing standards, as in Fig. 63.

When testing a meter installed with a current transformer, as an independent meter, the meter should be calibrated according to the accuracy curve previously determined when the meter and transformer were tested as a unit. (Fig. 65.)

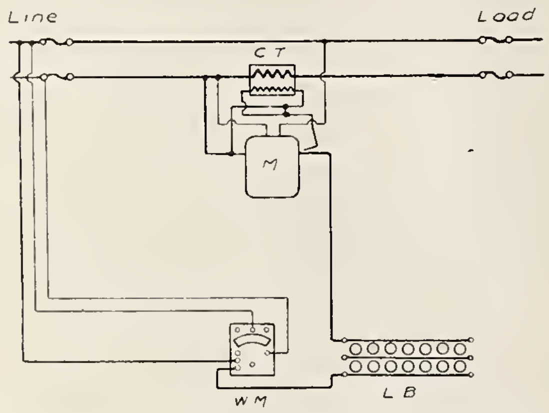


Fig. 65—TESTING A 100 OR 200-VOLT, ALTERNATING-CURRENT METER WITH CURRENT TRANSFORMER AS AN INDEPENDENT METER. THE TESTING CURRENT IS SUPPLIED TO THE METER DIRECT WITHOUT LOADING THE CURRENT TRANSFORMER

Fig. 60 illustrates the use of a current transformer connected backward across the line as a load device instead of a water rheostat, as in Fig. 59.

Temporary transformer *T* used as a load device in Fig. 66 is a regular 110-volt transformer connected across the high-tension circuit.

The potential circuits of standards should invariably be so connected as to receive the same voltage as the potential circuit of the meter, and be connected to the line side of the current coils of the meter under test.

The indicating wattmeter *WM* shown in the figures is equipped for two ranges of current in addition to two ranges of potential. The lower current range permits of more accurate readings on the lighter loads.

The shunt used in direct-current testing should, where possible, be connected to the grounded neutral of a 3-wire Edison system, to protect the instrument.

In all these diagrams, testing connections are made to the proper side of fuses, and this point must be carefully observed.

In Figs. 50, 53 and 58 the current coils are connected in series by the temporary bridging wire shown on the load side at the meter.

The potential of the meter shown in Fig. 58 is connected to 220 volts,

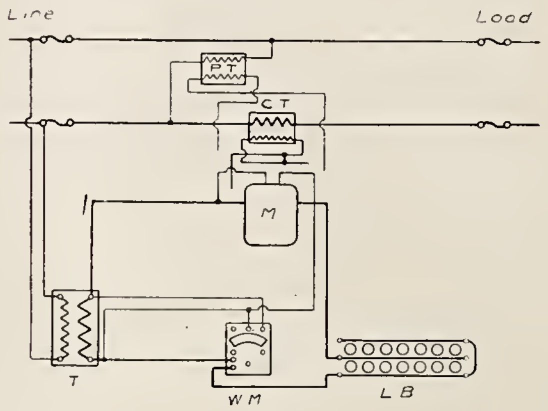


Fig. 66—TESTING ALTERNATING-CURRENT METERS INSTALLED WITH CURRENT AND POTENTIAL TRANSFORMERS. A SEPARATE TRANSFORMER SUPPLIES THE TESTING CURRENT

and since one outside fuse is removed it becomes necessary to disconnect the potential circuit from the current coil on this side of the line and supply it with voltage by a temporary jumper from the line side of the removed fuse.

Multiphase meters should be tested with the connections shown in Fig. 67. In this diagram connections are shown only for testing and calibrating one motor. It must be noted that while calibrating this motor the potential leads from the other phase must be connected to the meter, as otherwise the results obtained are inaccurate. It is necessary to duplicate the connections on the other phase and make the proper adjustments on that motor, so that both elements will be in calibration.

In addition to the method shown in Fig. 67, it is also possible but not advisable to test a multiphase meter on a single-phase circuit of the rated voltage and frequency of the meter. One method is to connect both potential circuits of the meter in parallel to the single-phase circuit. Each motor can then be tested separately and the calibration made as previously stated.

A multiphase meter may also be tested with the current coils of both motors in series and the potential circuits connected in parallel, as above. An objection to this method is the inability to determine any unbalancing of the motors, and when unbalanced any adjustments made would give in-

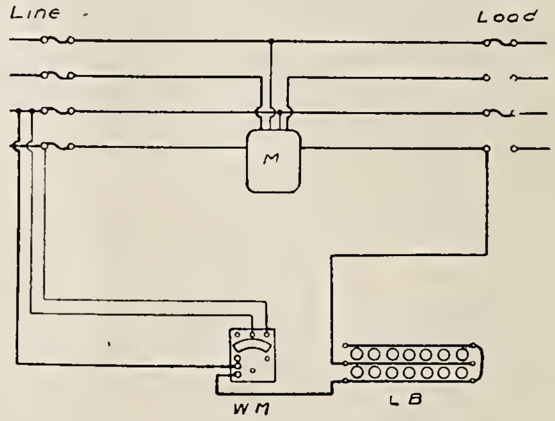


Fig. 67—TESTING CONNECTIONS FOR MULTIPHASE METERS. EACH MOTOR IS LOADED INDEPENDENTLY AND THE POTENTIAL CIRCUITS ARE CONNECTED ON THEIR PROPER PHASES

accurate results when the meter is connected to a multiphase circuit. When tested with both sets of current coils in series, one-half of the regular test constant is used in the calculations.

If either of the above methods are employed in conducting a test, care should be exercised not to reverse either of the potential circuits when connecting in parallel. When the current coils are connected in series the connections of one set of current coils should be reversed in order to secure the proper direction of current in the coils.

Owing to the possibility of inaccurate results and the inconvenience in making the proper connections, it is preferable to test each motor of a multiphase meter separately without disconnecting the potential circuits from the respective phases, as shown in Fig. 67.

LIST OF ABBREVIATIONS USED IN THE DIAGRAMS SHOWN IN FIGS. 47 TO 67, INCLUSIVE

B = Battery
CR = Carbon rheostat
CT = Current Transformer
HWM = High-capacity wattmeter
LWM = Low
LB = Lamp bank
M = Integrating wattmeter
Mvm = Millivoltmeter
PT = Potential transformer
R = Adjustable resistance
S = Shunt
SS = Series Switch
T = Temporary transformer
Vm = Voltmeter
WM = Indicating wattmeter
WR = Water rheostat

Illuminating Engineers' Society

The third annual convention of the Illuminating Engineers' Society will be held at the United Engineering Societies' Building, New York, Sept. 27-29.

The following list includes papers that are now being prepared for presentation. It is probable that others will be added to this list:

"Ethics of Illuminating Engineering," E. L. Elliott; "Some Notes on Illuminating Engineering Practice in Europe," H. Thurston Owens; "The Importance of Illuminometry in Practical Illuminating Engineering," Norman Macbeth; "Efficiency of Lighting Installations," A. L. Eustice; "Shades and Reflectors," Dr. Louis Bell; "The Design of Reflectors," A. J. Sweet; "Diffusing Mediums," A. J. Marshall; "Absorption and Diffusion of Various Forms of Glass Surfaces," Basset Jones, Jr.; "Factory and Mill Lighting," L. B. Marks; "The Photometric Laboratory of the United Gas Improvement Co.," C. O. Bond; "The New Physical Laboratory of the National Electric Lamp Association," E. P. Hyde; "The Problem of Heterochrome Photometry," P. S. Millar; "Description of a Demonstration Lighting Installation," W. C. Morris; "Discussion of the Efficiency of the Moore Light," Messrs. Hyde, Woodwell, Sharp and Millar.

Book Review

"Electrical Engineer's Pocket Book," by Horatio A. Foster, Consulting Engineer, with the collaboration of eminent specialists; Fifth edition, completely revised; p. 1599; price $5.00. D. Van Nostrand Co., New York.

Greatly revised and enlarged until no ordinary pocket could carry it, the new edition of Foster appears with 600 odd pages added to its already voluminous bulk—so fast the electrical art grows.

The book has been the standard work since 1902, and probably will continue to be, if the editing of the work remains in competent hands.

The aim of its publishers has been to present the data essential to the engineer in any branch of the art and the editors have succeeded very well in this respect, although they have perhaps overreached themselves a bit in including telegraphy, the theory of wireless telegraphy, and X-rays, etc.

The best executed chapters of the book are those on electric railway work, switchboard gear and illumination. The chapter devoted to direct-current motors is academic, and the testing of motors and generators is rather fragmentary in its presentation.

We are inclined to believe the editor has been a bit careless in his compilation work, since we find a description of the obsolete surface-contact system abandoned by the Westinghouse and General Electric Companies some years ago; since again we find only seven pages devoted to steam turbines, with absolutely no data on the Parsons turbine and very little on the Curtis machine; and, since again we find a nice, fine-spun theory of electrical resonance sandwiched in between "Electricity in the U. S. Navy" and "The Electric Automobile." These little discrepancies do not, however, mar the excellence of the work.

Unlike a fresh handbook the Foster manual of engineering has lived down any errors which crept into the early text and can be considered the most reliable work of its kind on the market. It ought to be the first purchase of any young engineer, for so much information can scarcely be covered in a dozen well-selected volumes.

New 200-250-Volt Tungsten Lamps

The advantages and economy of the tungsten incandescent over the carbon-filament lamp have been practically denied to most circuits operating at 200-250 volts, because the regular multiple tungsten lamps were designed for the standard voltage of 100-125. On these larger voltage circuits—for example, 220 volts—in order to use tungsten lamps at all it was necessary to operate two 110-volt lamps in series. Most users of the higher voltages preferred to wait for the advent of the tungsten adapted to their voltage.

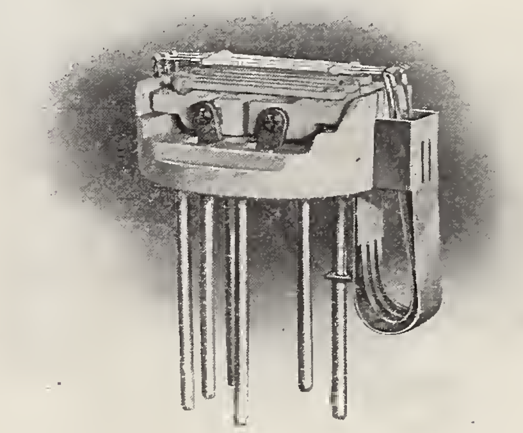
In answer to this considerable demand, the General Electric Company has extended its production of tungsten lamps into voltages from 200 to 250. This gives to the users of higher voltages the opportunity for the adoption of the economical high-efficiency lamps for multiple service. The regular 200-260-volt carbon-filament lamps ranged in nominal efficiency from 3.8 watts per candle to 3.1 watts per candle. The new tungsten has the usual tungsten efficiency of 1¼ watts per candle actual. The new lamps are claimed to possess all the excellent qualities of the regular General Electric 100-125-volt tungsten lamps, including the same form of specially anchored filaments which make the 100-125-volt lamps so successful. Tests of the new 200-250-volt tungsten show the average life and performance of these lamps to be fully up to that of the standard multiple lamps. The lamps have ratings of 45, 70, 110 and 180 watts.

The New Spring Holder

Another marked improvement in the Westinghouse Nernst system is the new spring holder.

This device makes the replacement of glowers so simple an operation that it can be done by anyone, without having had electrical experience. It greatly reduces the trimmers' time and makes it impossible for him to replace the glowers in any but the proper way.

The new holder consists of a one-piece porcelain base same as the old holder and receives the wafer heater in the same manner, but is provided with an entirely new device for holding the glowers. On one side there is attached a metal stamping consisting of a series of springs, one for each glower, covered by a metal guard. A corresponding number of rigid upright supports fit into the slots in the opposite side of the porcelain. Small platinum jaws to receive the glowers are welded to the tips of the springs and to the tips of the upright supports.



The glowers are provided with fused beads at the ends of their platinum leads which prevent them from slipping through the jaws of the holder. Replacement consists of the simple operation of inserting the bead of the glower in the jaw on the spring side of the holder and then drawing the spring forward sufficiently to allow the other bead to drop into the corresponding slot on the opposite side of the holder.

The spring tension is sufficient to draw the glower into place, which is done automatically without further attention on the part of the operator. Contact is made automatically. The pressure of the spring keeps the glowers in their correct position and does not permit them to assume any other position due to expansion and contraction.

The efficiency of the reciprocation engine increases 1 per cent for each 15 degrees of superheat.

Jeffrey Storage Battery

The accompanying illustration shows a new yard truck just brought out by the Jeffrey Mfg. Company of Columbus, Ohio.

The electrical equipment, including storage batteries, motor, controller, with all necessary charging instruments, are all located below the platform so that the truck can be used for carrying material of any kind, or for hauling yard cars. The design is such that it can be used on any gauge from 18 in. up, and on the shortest curves encountered on industrial tracks. The electrical equipment is furnished in sizes to suit the service.

For loads up to 10 tons a six-h.p. motor with a 10-kw. battery is provided. For heavier service larger motors and batteries are supplied, depending on the maximum loads and the frequency of the trips. The platform is made removable allowing easy access to the electrical equipment.

For the service usually encountered around the average manufacturing plant, moving raw materials, castings, etc., the 6 h.p. equipment will operate two or three days on a charge.

By estimating the average weight and average length of trip the proper size of equipment can be determined. The use of these cars facilitates the handling of material around a manufacturing plant, and also effects a very material saving in the cost of this work.

Gas Engine Installations Aggregating 210,000 H P.

In the accompanying illustration is shown an Allis-Chalmers horizontal, double-acting tandem gas engine, of 500 h.p., driving a direct-current generator of the same company's build in the power house of the Illinois Steel Company's Bay View mills at Milwaukee, Wis. During the two years this has been in operation, the unit has not cost $50.00 for repairs, and its record has been such as to demonstrate conclusively the reliability of gas engines, properly designed, for industrial service of the most severe character.

Machines in operation for about the same period of time, or longer, include gas engines and generators of from 300 to 5000 h.p. capacity, which, with others now going into commission, furnish power for iron works, steel mills, clay products plants, cement mills, automobile shops, plate-glass works, tube mills, wire works, central power, lighting and traction stations, phosphate plants, factories and other industrial establishments. In the list are engines operating on producer, natural and furnace gas and their capacity for continuous service aggregates no less than 210,000 h.p. Among the larger users of gas power in the industrial field is the Pittsburg Plate Glass Co., which was one of the earliest to install the improved type of engine and electric generator built by Allis-Chalmers Co., and has just placed an order for the eleventh of these units.

Allis-Chalmers' Orders

The effort that has been made by electric traction companies, despite the recent business depression, to keep their systems in good operating condition is not generally recognized; but one evidence recently brought to the attention of this paper is the fact that since January 1st of this year Allis-Chalmers Company, one of the largest builders of street and interurban railway apparatus, has received orders for nearly 1000 air-brake equipments. These include the company's latest type of straight air-brake equipments for single car operation, straight air-emergency equipments, combined straight and automatic air-brake equipments for two or three-car trains and automatic air-brake equipments for electric locomotives and heavy interurban trains. Among the companies buying are the following:

Tampa & Sulphur Springs Traction Co., Tampa, Fla.; Third Avenue Railway Co., New York; Tarrytown & White Plains Ry. Co., White Plains, N. Y.; Yonkers Street Ry. Co., Yonkers, N. Y.; Omaha & Council Bluffs St. Ry., Omaha, Neb.; Conestoga Traction Co., Lancaster, Pa.; Ogden Rapid Transit Co., Ogden, Utah; Atlantic Shore Line Ry. Co., Kennebunk, Me.; General Construction Co., Omaha, Neb.; Sandusky, Norwalk & Mansfield Ry. Co., Norwalk, O.; Shelbourne Falls & Colrain St. Ry. Co., Shelbourne Falls, Mass.; Chester Traction Co., Chester, Pa.; Lebanon Valley St. Ry. Co., Lebanon, Pa.; Rochester Ry. Co., Rochester, N Y.; Eastern Wisconsin Ry & Lt. Co., Fond du Lac, Wis.; Transit Supply Co., Minneapolis, Minn.; Chicago City Ry. Co., Chicago, Ill.

The Crocker-Wheeler Company has recently booked several large orders for direct-current apparatus. One of these from the Indiana Steel Co. calls for 70 mill motors, totaling about 2400 h.p. This ordr is an addition to the 11,000-h.p. of Crocker-Wheeler motors employed at the present time by this company. Another order from the Gould Paper Co., of Lyons Falls, N. Y., calls for electric drive for a new paper-making machine which they are about to install. A sale has been made to J. M. Kohler Sons Co., Sheboygan, Wis., of one 750-kw., 250-volt D. C. generator The King Bridge Co, Cleveland, O., recently placed an order for one 150-kw., compound-wound, 250-volt generator to be used for supplying light and power. Another sale made to the American Lace Manufacturing Co., Elyria, O., covered one 100-kw., 250 rev. per min. generator. The Bethlehem Steel Co. has recently added to their 8800 h.p. of Crocker-Wheeler motors, by an order for a 225-h.p., compound-wound motor, to be installed at their Saucon Plant. An order received from Beadleston & Woerz, New York City, covers 187 h.p. in compound-wound, 115-volt motors and one 150-kw., 125-volt compound-wound generator. Among orders for induction motors recently received by the Crocker-Wheeler Company is one from Roessler & Hasslacher Chemical Co., Perth Amboy, N. J., which totals 295 h.p. in 3-phase, 60-cycle, 480-volt motors of the squirrel-cage type.

Sharp-Threaded Star Bushings

The difficulties met with on the job when conduit bushings have flat threads, and the satisfactory results obtained with sharp-threaded bushings are graphically shown in a large and striking folder issued by the Steel City Electric Co., Pittsburg, Pa., makers of the well-known "Star" bushings. In a series of four large diagrams, there are presented examples of the effects produced with flat and sharp-threaded bushings and with conduit threads acid-eaten and standard. The information is interesting to the construction trade.

The New 150-Watt Tungsten

The General Electric Company has just listed a new 100 to 125-volt tungsten lamp. It is rated at 150 watts and supplied in 3⅜-in. pear-shaped bulb.

The lamp is designed to supply an intermediate unit between the 100-watt and the 250-watt types. Many central stations desire this lamp to replace gas arcs, for which the 100-watt lamp is too small and the 250-watt too large.

This new lamp has all the well-known and superior characteristics of the G. E. tungsten lamp the same excellent method of mounting and the special anchoring support for the filament which insures a maximum of mechanical strength and ability to withstand usage and permitting its satisfactory operation in any position. The lamp is listed at $2.50 plain, and $2.65 frosted; 24 in a standard package.

A number of interesting publications recently sent out by the Westinghouse Electric & Manufacturing Co., of Pittsburg, Pa., include the following: "Fan Motors for Alternating Current and for Direct Current"; "Luminous Radiators and Air Heaters"; "Battery Charging Methods," and "Multiple Tungsten Lamps."

The General Electric Company has just issued a bulletin devoted to searchlight projectors for commercial use. This publication contains illustrations and descriptions of projectors of various types and sizes, and goes, more or less, into detail. The use of searchlight projectors in connection with advertising purposes is constantly increasing, and this bulletin will be found of special interest along this line. Another bulletin, recently issued by the company, describes a current transformer for use in connection with the measurement of large amounts of current. These transformers are made in two forms: one containing both primary and secondary coils; the other containing only the secondary coil, the primary being composed of one or more turns of the cable carrying the current to be measured. The former transformer is designed to give three ratios of transformation; the latter, one. Each has a capacity of 40 watts,

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Among recent sales of heavy electrical machinery made by Allis-Chalmers Company is a contract covering two 3-phase, 25-cycle, 6600-volt, alternating current generators, with a combined capacity of 8000 kw., to be direct-coupled to gas engines in the power plant of the Carnegie Steel Company's Carrie Furnaces at Rankin, Pa. These are the largest machines ever built for service of this character.

News Notes

Recent sales of Allis-Chalmers electrical apparatus, exclusive of combined generating units, which constitute a large list in themselves, include the following:

Merchants' Heat & Light Co., Indianapolis, Ind., 2 1000-kw. Synchronous motor generator sets, 3 phase, 2300 volts, 60 cycle, A. C., 250 volts shunt-wound D. C., and 1 200-kw. shunt-wound balancing set, consisting of two 125-volt machines on a common cast-iron base; Delaware, Lackawanna & Western R. R., Hampton Power Plant, Scranton, Pa., 1 1500-kw. O. F. W. C., 3 phase, 60 cycle transformers, 4150/2200 volts; San Francisco Gas & Electric Co., San Francisco, Cal., 2 1000-kw. synchronous motor generator sets, 3 phase, 11,000 volts, 60 cycle, A. C., 275 volts compound-wound D. C.; Great Northern Railway Co., St. Paul, Minn., 9 induction motors, aggregating 220 h.p., 440 volts, 3 phase, 60 cycles; Joseph Light & Power Co., Joseph, Ore., 1 225-kw. A. C. waterwheel type generator, 2300 volts, 3 phase, 60 cycles, with exciter and switchboard; Portland Railway, Light & Power Co., Portland, Ore., 1 500-kw. vertical direct-current generator, 600 volts, with switchboard; Wind River Lumber Co., Cascade Locks, Ore., 1 100-h.p. induction motor, 3 phase, 60 cycle, 440 volts; Caldwell Milling & Elevator Co., Caldwell, Idaho, 1 100-h.p., 220-volt, 3 phase, 60 cycle induction motor; Pocahontas Consolidated Collieries Co., Switchback, W. Va., 1 175-h.p., 2080 volt, 3 phase, 60 cycle induction motor; Toleda & Indiana Railway Co., Toledo, Ohio, 1 400-kw. rotary converter, 500 rev. per min., 25 cycle, 3 phase, 600 volts D. C., with 3 150-kv-a. O. F. S. C. transformers 3200/375 volts, together with switchboard; Victor Talking Machine Co., Camden, N. J., 8 type "K" motors, aggregating 530 h.p., 220 volts D. C.; Goodyear Lumber Co., Tomah, Wis., 19 induction motors aggregating 925 h.p.; Crane Company, Chicago, Ill., 1 300-kw. synchronous motor generator set, 440 volts, 60 cycle, A. C. 250 volts D. C. and 3 100-h.p. induction motors, 440 volts, 60 cycles; Great Western Power Co, San Francisco, Cal., 15 O. F. S. C. transformers, 22,000/2400 volts, aggregating 2100 kv-a.

The contract for the construction work involved in the hydro-electric development of the Grand Falls Power Company on the St. John River at Grand Falls, New Brunswick, has been placed in the hands of the Frank B. Gilbreth Organization of New York. John B. McRae, of Ottawa, Canada, is the chief engineer and Ralph Mershon, of New York, is the electrical engineer for this work. This plant will generate 100,000 h.p., current being furnished to the various cities throughout New Brunswick and Maine. The work involves, among other features, the construction of a number of shafts in rock excavation 130 ft. deep, a power chamber 30 by 260 ft. and 130 ft. deep, and a tail-race tunnel 28 ft. in diameter and 2400 ft. long, a power-house 350 ft. long and 260 ft. wide. The intake shafts will be 9 in number and 12 ft. in diameter, 130 ft. deep. The total head developed will be 135 ft. Numerous auxiliary works, substations and long-distance transmission lines will be erected.

and may be used on circuits, the potential of which does not exceed 2500 volts. The transformers are portable, and are provided with carrying handles. A reprint of a paper on series Tungsten lighting, read by Henry Schroeder at the recent convention of the Northwestern Electrical Association, will also be found of value to those interested in this subject.

One way of determining the relative burning qualities of different shipments of coal is to weigh the coal fired during a definite period. This should entail no extra expense, as the coal passer, boiler washer, or ash wheeler, present in nearly every plant of moderate size, could be used during the few hours necessary for the test. The plan has one disadvantage in that there is possibility of variations in the amount of coal burned, due to the personal element involved. With the test by calorimeter, however, the measure of the calorific value of the coal is indisputable, while the expense involved should be more than covered by the saving obtained in rebates. A check on the first method would be to run the test two or three times under the same load conditions. In a case in mind, this method repeatedly demonstrated the fact that of two shipments of coal, it was required to burn a ton more of one in 24 hours. As this coal contained more slate than the better-burning coal, the results were in accordance with the observed facts.

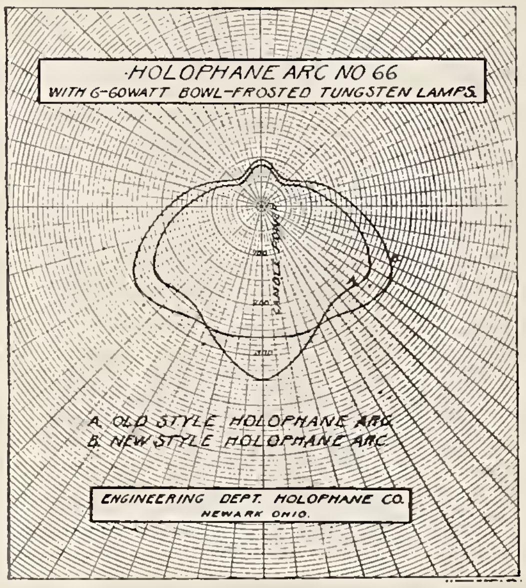
From the cases cited it will be apparent that attention to these matters will result in a reduction of the coal bill, and as the largest item of operating cost is found in the boiler-room, it seems only right that this end of the plant should receive a larger share of attention than is sometimes given it.

The New England section of the National Electric Light Association met September 9, 10 at Newcastle, N. H., in annual convention.

New Holophane Clusters

The Holophane Company, Newark, Ohio, has introduced improvements in the glass equipment of the Holophane "arcs" or clusters whereby a much better distribution of light is secured. The comparative curve here published indicates the improvement in this regard of the new units over the old.

A separable cluster body also is now supplied so that the new arrangement can be taken apart and the glassware cleaned without break the glassware cleaned without breaking the electrical connection. The standard finish of the clusters in future will be brush brass. Square-linked chain is used for the suspension, and a separable canopy is supplied, which does away with the necessity of a long nipple at the ceiling.



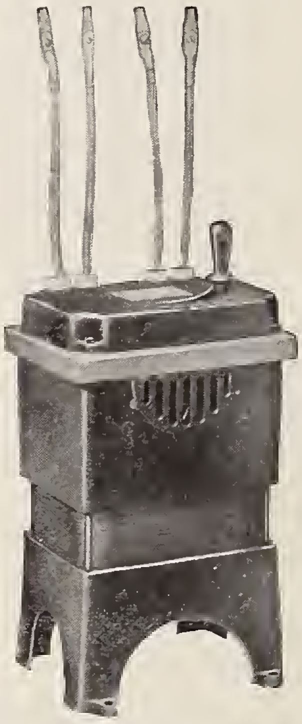
Note.—In the July issue the above statement was printed with the wrong curve. We have pleasure in showing herewith the proper curve for the new Holophane cluster.—Ed.

The Compensarc

The need of some kind of a device for controlling arc lamps on moving picture machines is obvious when it is known that moving picture machine arc lamps operate at approximately 35 volts at the arc, while the voltage obtainable from practically all commercial lighting circuits is either 110 volts or 220 volts. Some electrical device must of necessity, therefore, be used between the line and the lamp to take care of the difference in voltage.

The compensarc accomplishes this purpose on alternating circuits. It is in reality a special type of adjustable auto-transformer, and is manufactured by the Fort Wayne Electric Works.

This compensarc is known as Type A, Form 4, and is rated at two kilowatts for 110 volts or 2.5 kw. for 220 volts, and wound for either 60 cycles or 133 cycles, as may be desired.



FORT WAYNE ELECTRIC COMPENSARC

A horizontal, three-step, continuous circuit switch is mounted on the slate top, providing three adjustments for intensity of light. Each adjustment is so designed that it maintains approximately the same voltage at the arc while passing from one step to the next without at any time opening the circuit, which would consequently break the arc and produce flickering.

There is no waiting for the arc to settle and become steady before the intensity of the light can be determined. The compensarc increases or decreases the intensity of light without a flicker.

A cast-iron cover over the slate top completely encloses the switch blade and contacts, making it impossible for accidental short circuits to occur, and also removes all danger to the operator. The terminals to the line and lamp are brought out through porcelain insulators in the cover. The lamp terminals are plainly designated by the word "lamp" cast on the cover where the terminals come through. With a little care the compensarc can be installed by any operator.

The compensarc is approved by the National Board of Fire Underwriters. There is positively no fire risk, as there is no noticeable rise in temperature even after several pictures have been run through the machine.

Benjamin R. Western and W. Hull Western, until August 1, 1909, proprietor and manager of the Manufacturer's Advertising Bureau, 237 Broadway, and Walter Mueller and W. H. Denny, of the Banning Company, 225 Fifth Avenue, have organized the Manufacturer's Publicity Corporation, with offices at the Hudson Terminal Building, 30 Church Street, New York.

After a belt has been in use some time, its surface takes on a glaze. This results in losses due to slipping, always accompanied by heating, and draws the natural oils to the surface, causing them to evaporate. This condition further leads to the belt's getting stiff and hard and lessens the angle of wrap (the angle between the extreme points touched and covered by the belt on the pulley).

Without attention belts are almost sure to deteriorate as above described. Their efficiency is increased and their life lengthened according to the treatment they receive. To prevent the formation of surface glaze and the slipping accompanying it, it is the best practice to use a reliable belt dressing. This dressing should be of a nature that will not only offer temporary relief, but that will penetrate through the surface of the belt and replenish the natural oils. This will result in keeping the belt pliable and preserving the original efficiency.

Rosin is very frequently applied to prevent slipping, and this it will do, but at the same time it destroys the life of the belt itself.

Dixon's traction belt dressing has through long service proved its value in preserving belts at high efficiency. It does not supply a surface stickiness but is absorbed by the belt, thus keeping it in its natural condition, preventing the formation of surface glaze with the attendant slipping, and maintaining the angle of wrap at its widest points.

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NOTICE TO ADVERTISERS

Insertion of new advertisements or changes of copy cannot be guaranteed for the following issue if received later than the 15th of each month.

CONTENTS

An Apology to the Rubber-Covered Wire Engineers' Association

In the September number of THE ELECTRICAL AGE under the caption of an editorial appear some aspersions on the Rubber-Covered Wire Engineers' Association which we wish editorially to disavow. The sentiments expressed therein were those of an individual engineer, and as such ought if published to have appeared as a communicated statement and not as a definite editorial expression.

But since the publication of the article referred to above, we have received letters indicating an interest, at once real, querulous and desirous of information. We, therefore, feel inclined—nay, urged—to say something of the trade conditions which led to the formation of the Rubber-Covered Wire Engineers' Association and its specifications.

The production of an insulating compound involves questions of physics, chemistry and physiology; physics, because the compound must have certain electrical and mechanical qualities; chemistry, because of the compounding of substances; and physiology, because rubber is an organic compound of cellular nature and a knowledge of its cellular properties is important.

At the present time the chemistry of rubber compound has scarcely reached the dignity of a science, as it is not possible to *predict* with any degree of certainty what properties a compound of given composition will have. This condition is due to the inherent complexity of the subject rather than to any lack of scientific investigation by the manufacturers. *Certain* manufacturers have conducted very systematic experiments to discover any *laws* which might exist connecting the various chemical and physical qualities of compounds, and for this purpose have employed some of the most competent experts on the chemistry of rubber.

A study of this kind is too complicated to be under accurate scientific control and the experiments of various manufacturers, being free from such control, led to the evolution of widely different results, a condition which was fostered by attempts at secrecy. This condition led to the issuance of various specifications by the manufacturers, each of whom emphasized the importance of certain qualities which his compound possessed to an unusual degree, thereby attempting to create an impression of having a monopoly of the only perfect compound. It is only fair to add that some manufacturers refrained from this kind of advertising and were content to obtain sales on the basis of their good records.

The practice of associating certain arbitrary qualities of compounds with the quality of excellence was probably originally no part of the program of the manufacturers themselves. It was the trick of the individual salesmen in many cases. One salesman who represented a firm making a black compound tried to make people believe that blackness was an essential quality of good compound. Many good people consequently specified "Compounds shall be black." Another salesman who represented a firm making a compound of high specific resistance proclaimed to the world that the essential quality of a permanent rubber compound was high specific resistance. People who knew no better immediately ran up the megohms and put many first-class firms out of competition and forced them to make new and untried compounds to meet the absurd conditions.

One manufacturer of note advocated testing the insulation before the application of tape, because in his process taping was performed after vulcanizing the compound with the tape on. The salesman of the first company tried to exclude these other firms by persuading the unwary to specify testing before taping.

A prominent firm advised an inelastic compound recommending that for certain classes of work the elasticity be limited to a certain low maximum. Other firms insisted upon high elasticity. Consumers specified each way!

These are a few of many similar instances. In some cases crafty consumers combined the requirements of all the salesmen who visited them and produced artistic specifications which called for impossible combinations of qualities.

Wonderful and fearful were the specifications which the manufacturers received. There was telephoning, telegraphing and rapid trips of the salesmen to misled customers.

"No, sir," the consumer would say, "I will have a pea-green compound or none. How do I know that pea green is the only reliable color? Well, Jones of the Hiberman Rubber Co., says so, and he's been in the business for thirty years. Then Robinson of the Interurban Lighting Co., who has just bought fifty thousand dollars worth of rubber-covered wires, says that a compound is worthless unless it's green. That's good enough for me. You had better go back to Schedunk, young man, and tell your firm to learn something about rubber before they teach me!"

This sort of thing finally brought the manufacturers together for mutual assistance, and no wonder. They were reaping the harvest of their salesmen's iniquities.

When this interesting phase of the rubber business was finally unbearable, the manufacturers formed an association, to which they gave the name of "The Rubber-Covered Wire Engineers' Association."

The specifications, which were drawn by the association of manufacturers, are in very general use, though some of the telephone and railway companies who have much experience in these matters and who have specially severe conditions to meet, elect to draw their own specifications.

Regarding the specifications themselves, there have been minor objections to them which seem well-founded and we mention a few of them:

We shall quote a sentence or paragraph at a time and state the objection to it voiced by many engineers, confining ourselves to chemical and mechanical matters.

"The compound shall contain not less than 30 per cent. by weight of fine dry Para rubber which has not previously been used in rubber compounds. The composition of the remaining 70 per cent. shall be left to the discretion of the manufacturer."

Suppose, as is the case with several manufacturers, that shoddy (*i. e.,* reclaimed rubber) is used in the remaining 70 per cent. of compound.

No chemist in the world can analyze the compound so as to tell the amount of dry Para rubber present. Fine dry Para rubber can be known only by the amount and nature of the extractive matter. If the compound contains new Para rubber and shoddy it gives the same analysis as a superior shoddy.

Then the specifications later say that "The purchaser may send to the works of the manufacturer a representative who shall be afforded all necessary facilities to assure himself that the 30 per cent. of rubber above specified is actually put into the compound." This provision is not as effective as it appears to be. The inspector does not live on the job and it is as easy to accept the manufacturer's word that the compound is as specified as it is to accept his statement that the compound into which the rubber was put is the same as that finally delivered. We do not see the logic of accepting an implied good faith in preference to a direct statement. It seems easier to accept the statement of the manufacturer's engineer that 30 per cent. of Para rubber is used than to accept that of the shop foreman that his scales are correct, and that the compound that we see is that which is going to be delivered. As a matter of fact, the word of a reputable house is sufficient in a matter of this kind.

Here is another clause:

"The vulcanized rubber compound shall contain not more than 6 per cent. by weight of acetone extract."

Certain dry mineral compounds with 6 per cent. of extract would be worthless. It is useless to specify the percentage of extract without narrowing down the range of compounds which will be acceptable. One excellent compound contains over 30 per cent. of extract, a quality which would be absurd in compounds of another type. Some manufacturers use a very little extractive matter; others use a great deal. For the usual type of compound manufactured by the firms represented in the Rubber-Covered Wire Engineers' Association 6 per cent. of extract seems unnecessarily high.

The clause about the Soxhlet extractor is very practical. This apparatus is the most improved form of extractor for removing the resinous matter from rubber. It is used by the majority of chemists who are engaged in the analysis of rubber, and a complete extraction may be made with it in about two days. The reduced time recommended by the Rubber-Covered Wire Engineers' Association prevents the complete extraction of soluble matter, but sufficient extraction takes place for most practical purposes, while a complete rubber analysis is very difficult to make and requires considerable technical knowledge. The test with the Soxhlet extractor is simple and the apparatus can be made up without great difficulty. For such an analysis, analytical chemists usually ask from 10 to 20 dollars, and there is no excuse for a consumer omitting this test.

"The rubber insulations shall be homogeneous in character."

Exactly what that means we do not profess to know. Probably it means "homogeneous in structure."

If so, it is not true of thick insulation, which is more thoroughly vulcanized on the surface than inside.

The clause about tensile strength is excellent:

"From any wire on which the wall of insulation does not exceed 4/32 in., a sample of vulcanized rubber compound not less than 4 in. in length shall be cut with a sharp knife held tangent to the copper. Marks should be placed on the sample 2 in. apart. The sample shall be stretched until the marks are 6 in. apart and then immediately released; one minute after such release the marks shall not be over 2⅛ inches apart." Just what the framers of the specifications intended this test to require is difficult to see. We have seen 30 per cent. Para compounds which could not meet this test and 15 per cent. Para compounds which could.

We cannot too strongly emphasize the fact that a clause like this is quite ineffective unless combined with other requirements which have the effect of narrowing down the acceptable compounds to a single type.

"The sample shall then be stretched until the marks are 9 in. apart before breaking."

This is a conservative requirement, but it is not often that the ordinary stuff on the market will stand this test. This may be due in part to the difficulties of the test. The slightest irregularity on the surface serving as a starting-point for premature tearing when the sample is stretched. It is due in a greater measure, however, to the fact that the compounds are generally intrinsically defective in tensile strength.

The paragraphs on thick samples, defective samples and temperature restrictions are unobjectionable.

"For high-tension service it is recommended that the above mechanical requirements of the rubber be eliminated."

For high-tension service, it is undoubtedly a fact that an elastic compound is usually inferior, because high dielectric strength can be obtained only at the sacrifice of elasticity. Let us, however, consider the effect of leaving out the mechanical requirements. What is left? A request for 30 per cent. of Para rubber and a requirement that the electrical properties shall come up to certain simple standards. An engineer wants to buy some rubber insulated cable for 20,000-volt service and wants to be sure that he is getting the very best, what does the Rubber-Covered Wire Engineers' Association tell him to ask for? It says, ask for 30 per cent. of Para rubber, see that your megohms are moderately high and that your dielectric strength is adequate, and you will get what you want.

The above remarks only lightly cover the ground and we wish we could discuss the subject at greater length; but if what we have said will set some of us to thinking much good will have been done.

It is probable that nothing better than the present comprehensive specifications could have been written to cover all types of compounds. We are, however, of the opinion that better results could be obtained by having separate specifications for different types of compounds; one for high-tension insulation, one for low-tension insulation with modifications according to whether the compound is to be used indoors or out of doors, and according to other important conditions.

We may have something to say about the electrical requirements in another issue, when we shall express opinion as to the best way to secure standard rubber specifications.

A Swiss Power Plant

Engelberg, Lucerne

by **STEPHEN Q. HAYES,**

Electrical Engineer

The design of European high tension transmission plants differs in so many particulars from that to which American engineers are accustomed that a short description of the plant installed by the Oerlikon Company of Zurich for transmitting power from Engelberg to Lucerne may be of interest.

This installation, completed a few years ago, comprises the generating station of Engelberg, the line, 27 km. in length, from Obermatt to Lucerne, transformer station at Steghoff near Lucerne, as well as small substations for light and power located along the transmission line.

Like most Swiss plants, the power is developed by water wheels operating under a high head and the hydraulic and electrical features are well worked out.

The water reservoir is located in a high valley fed by springs, and as it is situated in the region of the snows there is no trouble from low water in summer. This reservoir has a capacity of about 2,500,000 cu. ft., and there is an effective head of nearly a thousand feet available with a sufficient flow of water to develop from 12,000-15,000 h.p. during the summer months.

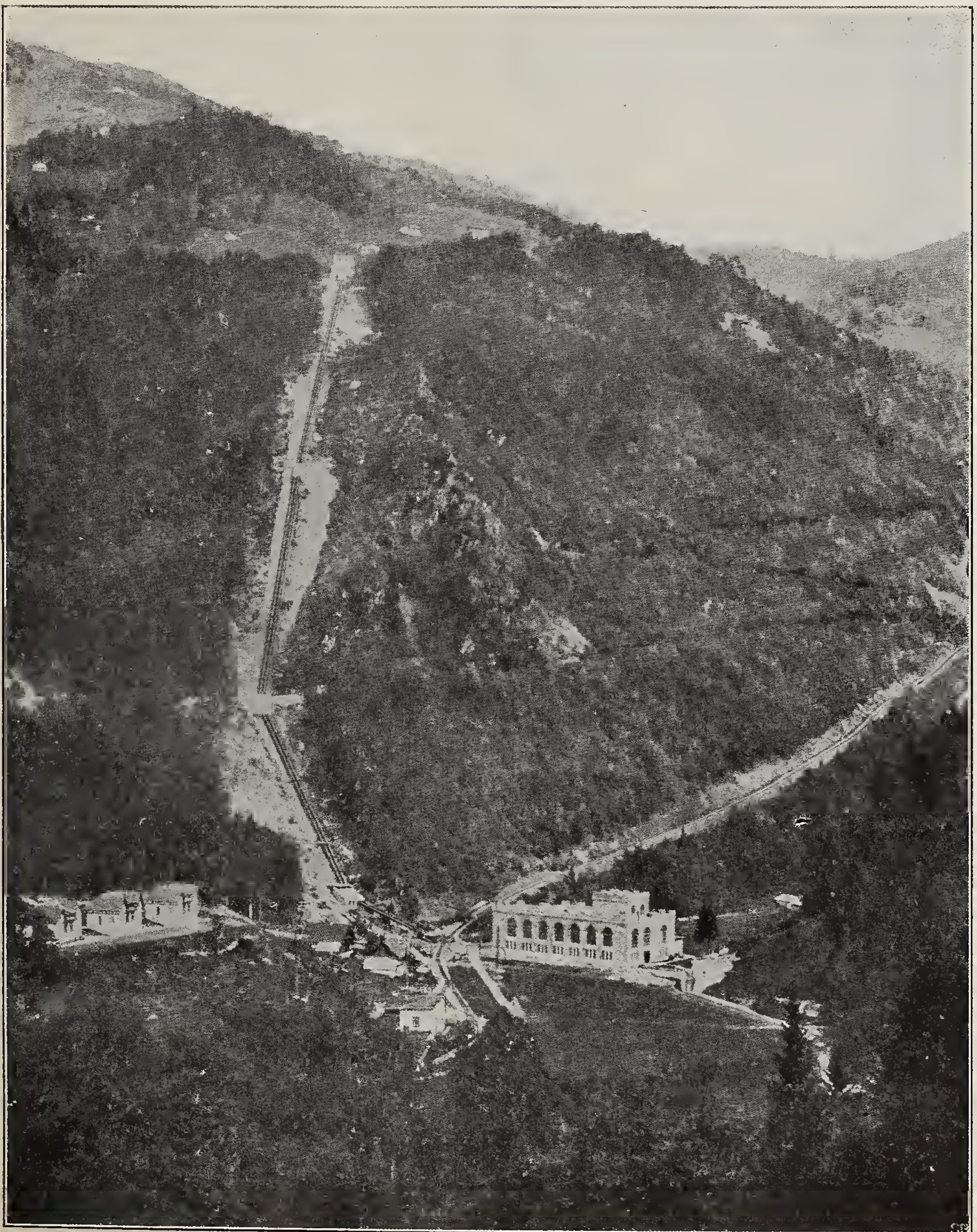


Fig. 1.—OBERMATT GENERATING STATION, EXTERIOR.

Fig. 1 shows the exterior of the generating station at Obermatt with the gate-house and the penstocks. This gate-house connects with the reservoir by a canal about a mile and a half long, with a slope of 1.2 per cent. Most of this canal is through a tunnel with a section of about 45 sq. ft. From the gate-house to the generating station two penstocks have been run with provision for two more. These penstocks, about 2000 ft. long, are anchored at five points in massive concrete blocks with expansion joints between each pair of anchorages. The penstocks of steel plate are about 40 in. diameter at the top and 36 in. at the bottom, where the regulating and discharge gates are placed. A tail race about 850 ft. long conducts the water to the river.

Fig. 2 shows the interior of the generating station at Obermatt, and clearly indicates the relative location of the exciters, generators, control platform, switching-room, etc.

All of the turbines in this station are of the Pelton type and are provided with hand regulation as well as automatic. There are two 150-h.p. turbines driving the exciters, one 600-h.p. driving a generator for the Stansstad Engelberg Electric Railway, and four 2000-h.p. wheels driving the main generators.

This generating station is divided into three long rooms, containing the machines, the transformers and the switching apparatus. The machine room, 180 ft. long, 43 ft. wide and 40 ft. high, has been designed to accommodate six 2000-h.p. generators, of which four are installed, and three 150-h.p. exciter sets, of which two are installed, and the building can be extended to take eight generators.

The exciters have a normal output of 100 kw. at 100 volts, with a maximum voltage of 150, and a speed of 700 rev. per min. These machines are shunt wound and have an efficiency of 92 per cent. at full load, 90 per cent. at half load, and their armatures are drum wound with open slots. As an additional source of excitation in case of emergency a storage battery of 56 cells with a capacity of 1000 ampere hours is installed. This is charged from one of the exciters, and

a motor-operated end-cell switch with column type indicator is furnished.

The generator for railway service is connected to the 600 h.p. turbine operating at 490 rev. per min. and has an output of 520 k.v.a at 780 volts 32½ cycles and has an efficiency of 94 per cent. at full load, 100 per cent. power factor, 91 per cent. at full load, 75 per cent. power factor.

The 50-cycle main generators can be used either as single-phase or three-phase machines and each machine can develop 1850 k.v.a. three-phase, or 1380 k.v.a. single-phase 6000 volts, 300 rev. per min. with 100 volts field excitation. These machines are of the rotating field type with horizontal shaft and are connected to the turbines by rigid couplings. The frame is of cast iron and the laminations are placed in dovetailed keyways and are held between steel end rings. The armature coils are placed in open slots, nine per pole, and are insulated by means of seamless micanite tubes and held tightly by fiber wedges.

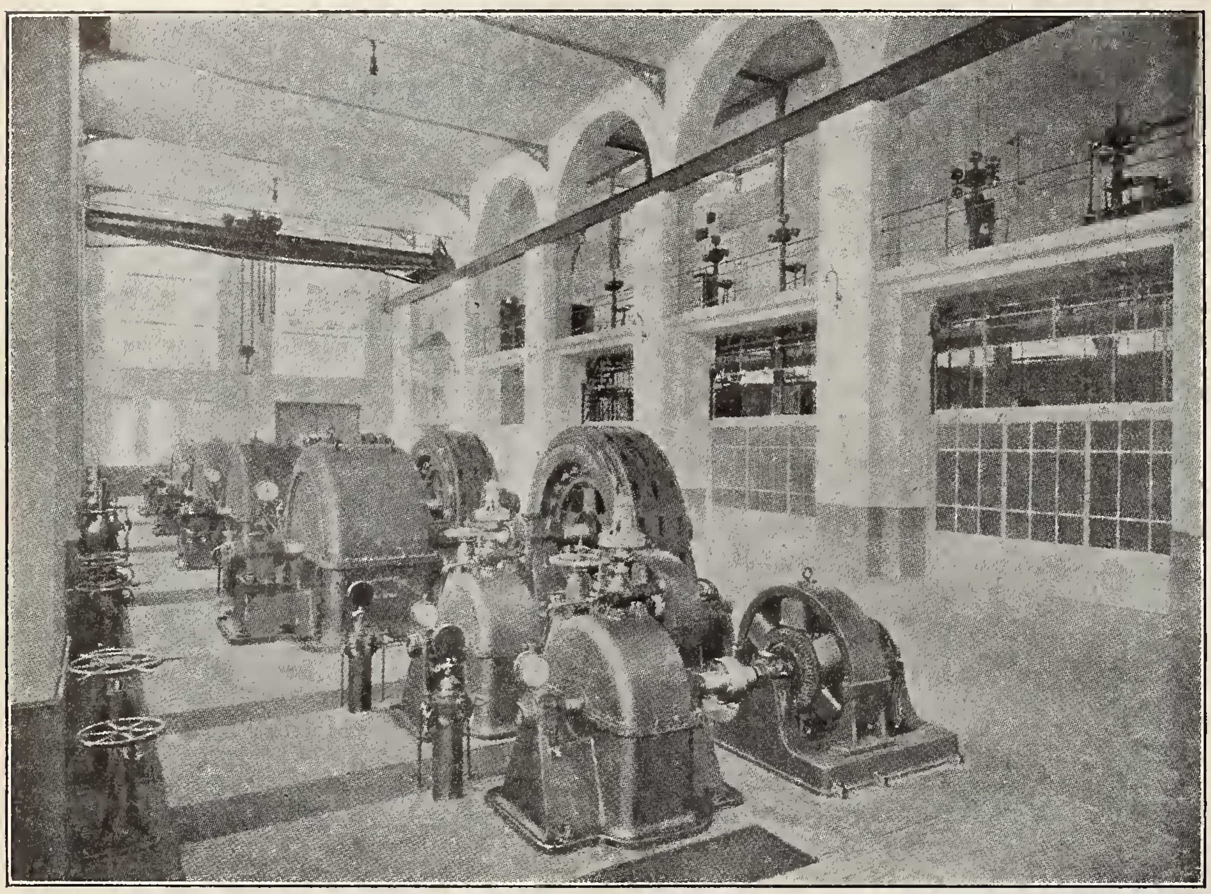


Fig. 2.—OBERMATT GENERATING STATION, INTERIOR.

The field ring is a star-shaped casting, keyed to the shaft, and holding four cast-steel rings to which the 20 laminated poles are attached. The spaces between these rings form ventilating ducts that register with corresponding ducts in the pole laminations. The field coils are of copper strap, and carbon brushes are used for carrying the current to the collector rings.

The full-load efficiencies are 96 per cent. for 100 per cent. power factor, 95 per cent. for 75 per cent. power factor, while at half load the efficiencies are 93 per cent. and 92 per cent. Full load excitation amounts to 9 k.w. at 100 per cent. power factor, 20 kw. at 75 per cent. regulation, 7 per cent. at 100 per cent. power factor, 17 per cent. at 75 per cent. Temperature rise at full load 40° C., overload 25 per cent. for two hours with 50° rise. Insulation test 12,000 volts for armature, 500 for field. Machines will stand a double speed test.

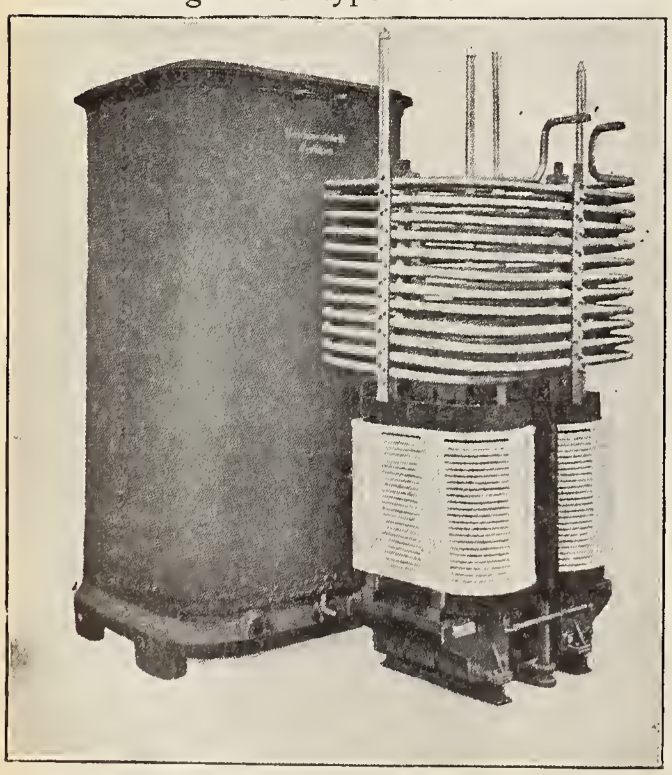


Fig. 3.—700-KVA. SINGLE-PHASE TRANSFORMER.

In order to step up the voltage from 6000 to 27,000 there are two banks each of three 700 k.v.a. single-phase transformers with one spare for the three-phase service and three units of the same size for single-phase. These transformers, as shown in Fig. 3, are core type transformers, oil-immersed, water-cooled, in riveted plate tanks. The laminated cores are rectangular in shape and the low tension windings of bare copper ribbon wound in spiral coils are placed next the core. These coils are placed one over the other and suitably insulated. Vertical wooden blocks regulate uniformly the distance between the low-tension windings and the core. The high-tension coils are placed outside and insulating barriers of impregnated paper and mica separate the windings. The high-tension windings are subdivided into a large number of coils and the maximum potential difference between adjacent coils cannot exceed 900 volts.

These transformers have a full-load efficiency of 98 per cent., half load, 97 per cent. regulation at full load, 75 per cent. for 100 per cent. power factor and 3½ per cent. at 75 per cent. power factor. Temperature rise 40° C. above the cooling water, of which about 38 gal. per minute will be required. These transformers will carry 50 per cent. overload for half an hour, and 25 per cent. for two hours, and will stand an insulation test of 54,000 volts for one minute.

The general scheme of connections is such that any of the 50-cycle generators can feed through an overload oil circuit breaker and suitable knife-type disconnecting switches, either the single-phase or three-phase 6000-volt bus. These bus bars are arranged to form two complete rings with knife switches for sectionalizing the rings.

Fig. 4.—CONTROL PEDESTALS IN OPENING GALLERY.

The three-phase bus is also provided with an oil breaker for sectionalizing and the two banks of step-up transformers are connected on each side of the section breaker. The three-phase groups are connected delta delta

and knife switches are provided for cutting out any one transformer of either group and cutting in the spare transformer.

The high-tension side of the step-up transformers connect to three-phase or single-phase ring bus bars and the three 27,000-volt outgoing feeders can be connected to either the three-phase or single-phase bus.

This series of ring bus bars is typical of European practice, and while it permits a great deal of flexibility it occupies a large amount of space, and in the opinion of most American engineers the same number of switches and the same or smaller amount of material can usually be utilized to better advantage in a double-throw system. The entire separation of the single-phase lighting load from the three-phase power load involves more complication than would usually seem to be justified.

As may be noted from Fig. 2, the control gallery overlooks the generator room, and in this gallery, as shown on Fig. 4, are placed the generator control columns and the outgoing line panels. The generator columns on the right contain a single-phase indicating wattmeter with Y box, an alternating-current ammeter, a double-scale voltmeter with one scale indicating the generator voltage and the other used as a phase voltmeter for synchronizing. The column also contains the levers to operate the oil-circuit breakers, switches for light and power, rheostat handwheels and the carbon breakers of the field circuits.

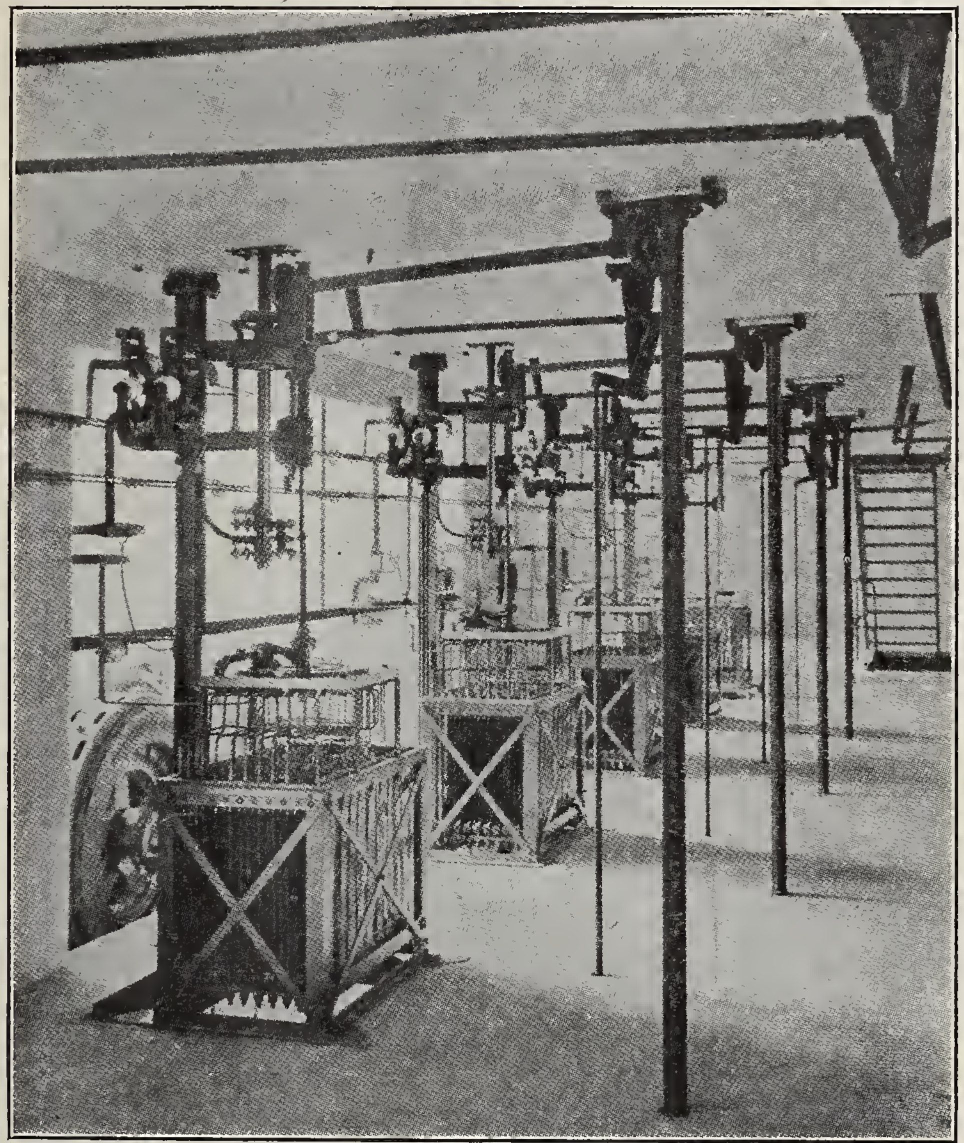


Fig. 5.—FIELD CONTROL EQUIPMENT.

A very ingenious arrangement of the levers makes it necessary for the attendant to perform his various operations in proper sequence. The oil-circuit breaker cannot be closed if the field switch is open, and conversely, unless the oil circuit breaker is open the field switch cannot be opened nor the knife switches connecting to the bus manipulated. The voltmeters and wattmeter are automatically connected by the movement of the operating lever in such a way as to give proper indication without any further trouble. A white lamp shows when the breaker is closed and a red one when open. An accoustic signal operates on the opening of a breaker, but this can be cut out immediately by hand if desired.

The battery control pedestal carries two ammeters, a voltmeter switch, handles for two breakers as well as for the end-cell switches and two control indicators.

The exciter columns contain a voltmeter, ammeter, field rheostat handwheel and two levers to work the circuit breaker and switch. A suitable interlock between the switch and circuit breaker is provided.

The sectionalizing switches in the main bus bars are operated from this control platform.

A panel switchboard, seen at the far end of the gallery next the wall, controls the outgoing lines. The first panel controlling the Engelberg cirsuit has two signal lamps and three ammeters. The three high-tension line panels each have three ammeters, the handle for the oil-circuit breaker, two signal lamps and the handwheel for operating the double-throw knife-switch connecting to the light or power bus. The last panels contain Hartman & Braun static voltmeters with condensers and carbon resistances connected between the 27,000-volt bus bars and the ground.

The lighting switchboard, seen on the left towards the front, takes care of the circuits to eight arc lamps and a large number of incandescent lamps

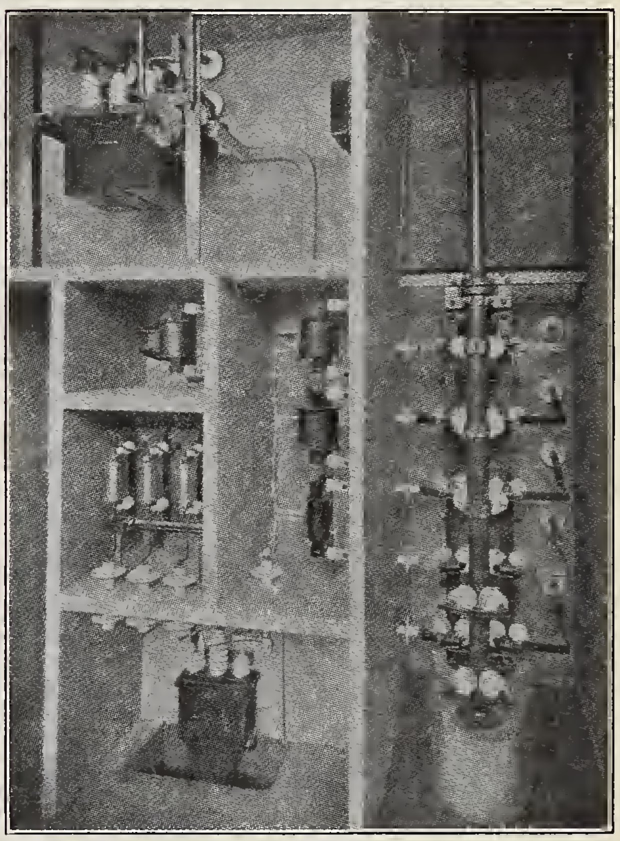


Fig. 6.—GENERATOR CONTROL APPARATUS.

that are used. This switchboard, like the one for the outgoing lines, is provided with white marble panels set in the front of a metal cabinet, the ends and lower part of which are covered by perforated sheet iron.

For paralleling the alternators, synchronizing voltmeters are used and synchronizing lamps are placed at each machine. A Westinghouse synchroscope is also installed and has been found to be of great service. On the main wall of the station, facing the operating gallery, have been placed two illuminated dial voltmeters with a scale 40 in. radius to show the pres-

sure on the lighting and power circuits.

On the gallery, below the operating gallery, are located the field rheostats, field switches and as shown in Fig. 5. The exciter and field bus bars of bare copper strap are mounted on porcelain insulators at the front of the gallery and connect through the mechanically operated field switch to the rheostat and the field of the generator. The field rheostat face plates are mounted horizontally above the resistances and the contact arms are turned by vertical shafts from the operating gallery above. The bell crank mechanism shown in the cut works the generator circuit breaker on the floor below, while the bevel gear mechanism operates the knife switches that connect the generator circuit either to the lighting bus or the power bus.

Fig. 6 shows the apparatus provided for the control of one of the main generators. The generator leads are brought as a three-cored cable to the bell shown in the bottom left-hand compartment. A three-phase voltage transformer with porcelain fuse holders is placed at the left while four current transformers are in the center and are used, one for the ammeter, one for the wattmeter, and two for the three-pole, automatic oil circuit breaker that is located in the upper left-hand cell. After passing through the breaker the current goes either to the lighting bus or to the power bus, depending on the position of the three-pole double-throw switch in the right-hand compartment. As may be noted, the cellular construction is used with the horizontal and vertical barriers of concrete. The right-hand lead from the cable bell passes through a porcelain bushing in the horizontal shelf to the three series transformers in the central compartment and then through a bushing in the vertical back wall to a compartment that contains the connections to the oil circuit breaker. The central and left-hand lead from the cable bell pass through bushings in the back wall and then up to the circuit breaker, one of the leads passing back and forth through this wall to the fourth series transformer. The leads to and from the circuit breaker also pass through the back wall to the wiring compartment. The secondary leads to the trip coil of the breaker are run in a concrete-covered conduit as shown.

Fig. 7, the 6000-volt oil circuit breaker clearly indicates the general design of this piece of apparatus. All of the contacts are placed in a single oil tank made of sheet metal with barriers between the poles, and while the breaker is substantially built, it is considerably smaller than would be con-

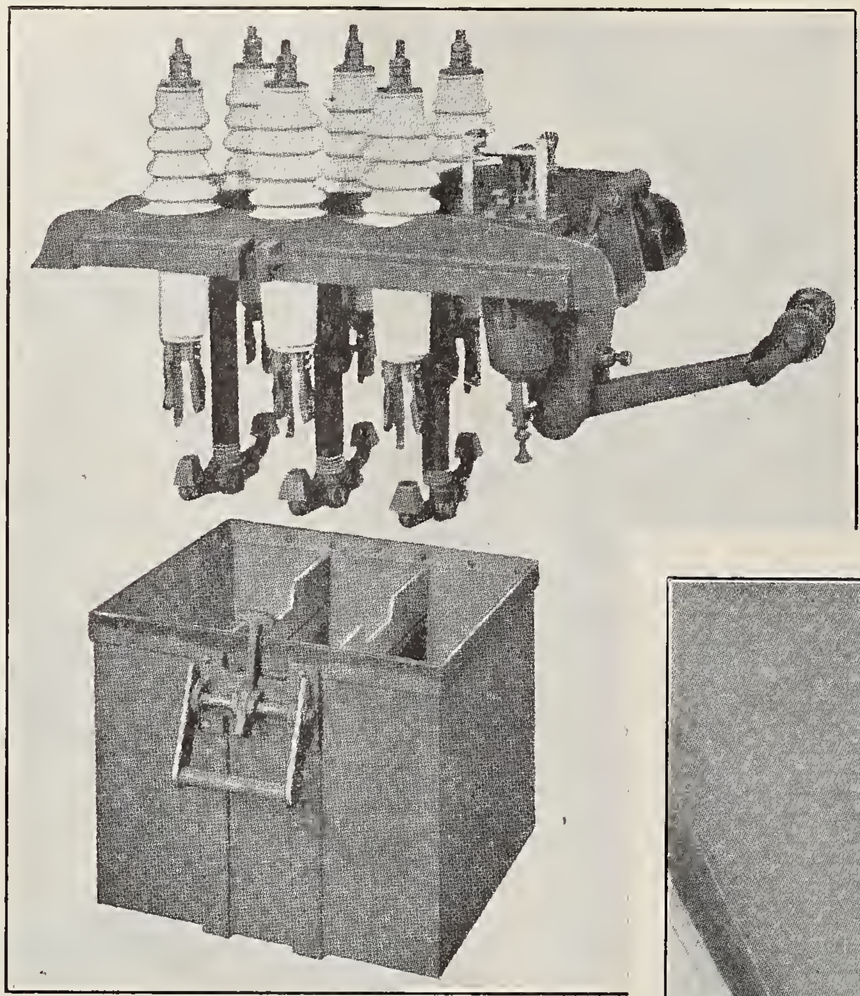


Fig. 7.—6000-volt oil circuit breaker.

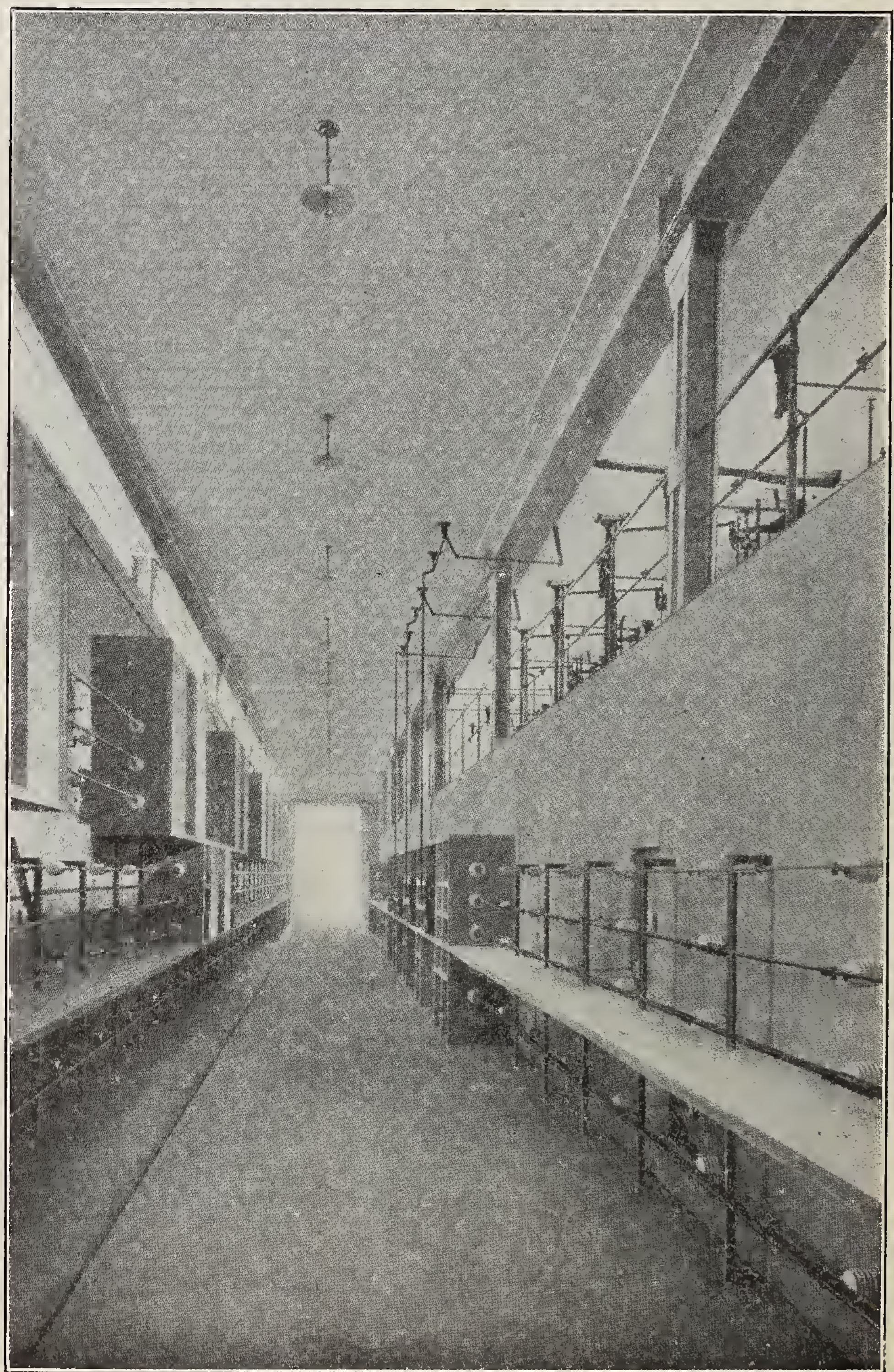


Fig. 8—6000-volt bus bars.

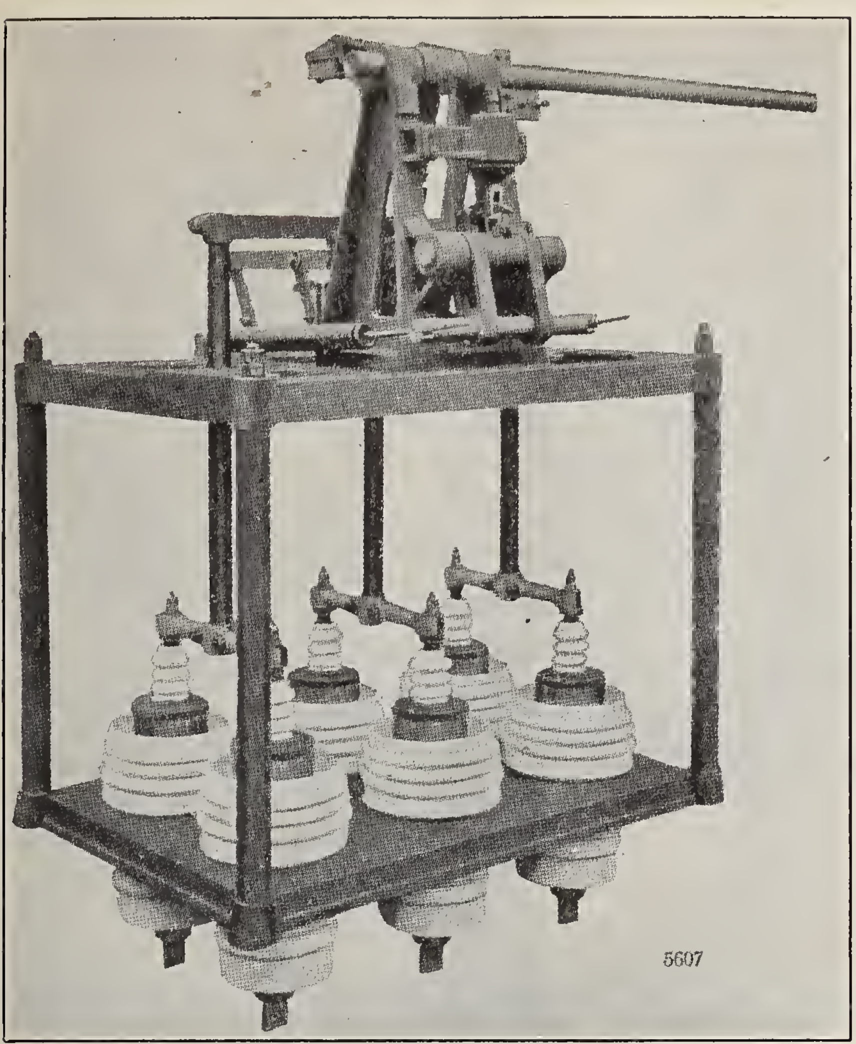


Fig. 9.—27,000-VOLT OIL CIRCUIT BREAKER.

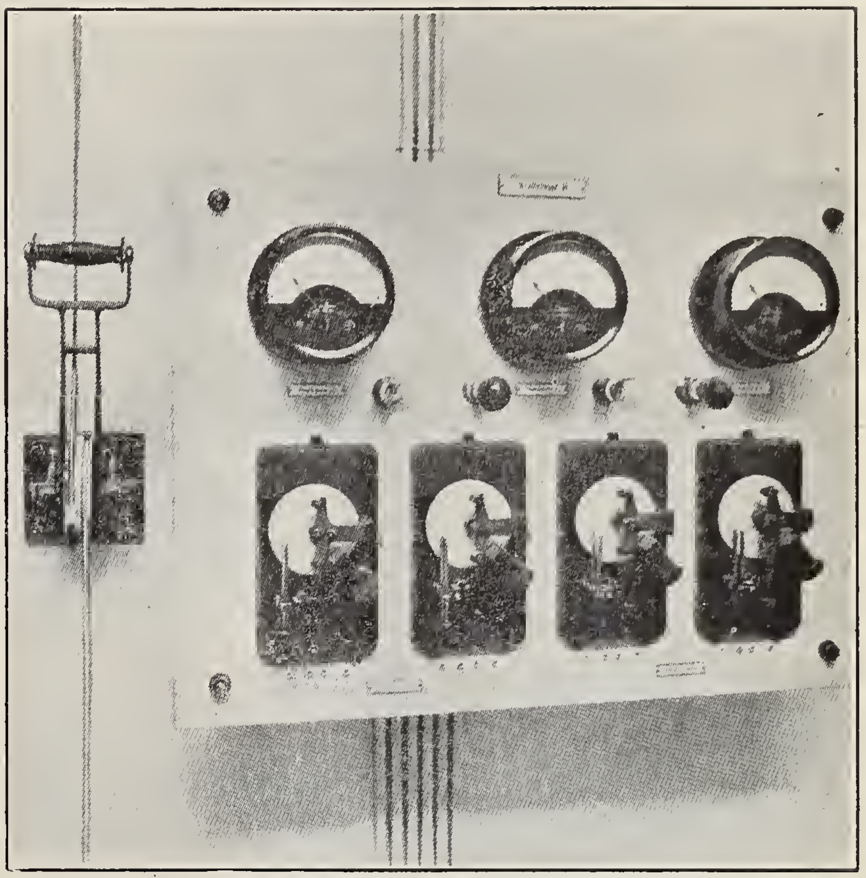


Fig. 10.—PANEL FOR TRANSFORMERS.

sidered safe in America for a plant of the same capacity. The generator breakers are provided with a time-limit relay and are made automatic, also a departure from American practice.

Fig. 8 shows the 6000-volt bus bars which are placed in the central portion of the ground floor. The generator breakers are located on the far side of the right-hand wall while the transformer breakers are placed on the far side of the left-hand wall. The busses of bare copper strap mounted on porcelain insulators form a complete ring, with the generators feeding in on one side and the Engelberg line and the low-tension end of the transformers feeding out on the other side. The mechanism for operating the bus sectionalizing switches can be seen at the right near the center.

Fig. 9 shows the type of oil circuit breaker used on the high-tension side of the step-up transformers and the 27,000-volt outgoing feeder circuits. This has two breaks per pole, each break occurring in a separate pot, the connections being made at the bottom of these pots and all of the mechanical parts being mounted on an upper framework. This breaker, like all bottom-connected ones, has the disadvantage that gravity tends to close it instead of open it, and sediment is apt to settle on the contacts at the bottom of the oil pots. This breaker, as well as that for the 6000-volt circuits, is arranged for rope operation from the handle shown to the left of the transformer panel in Fig. 10. The rope running upward operates the high-tension breaker while the one running downward actuates the low-tension breaker of a transformer bank so that the high-tension and low-tension connections are made at the same time.

The panel contains two white lamps that light up when the breakers are closed and two red lamps that light when the breakers are open. A bell is also supplied that rings when the breakers come open automatically and the bell circuit can readily be disconnected if it is intended to leave the breakers open. Relays and ammeters for the transformer circuits are also mounted on this panel.

Fig. 11 shows the upper part of the

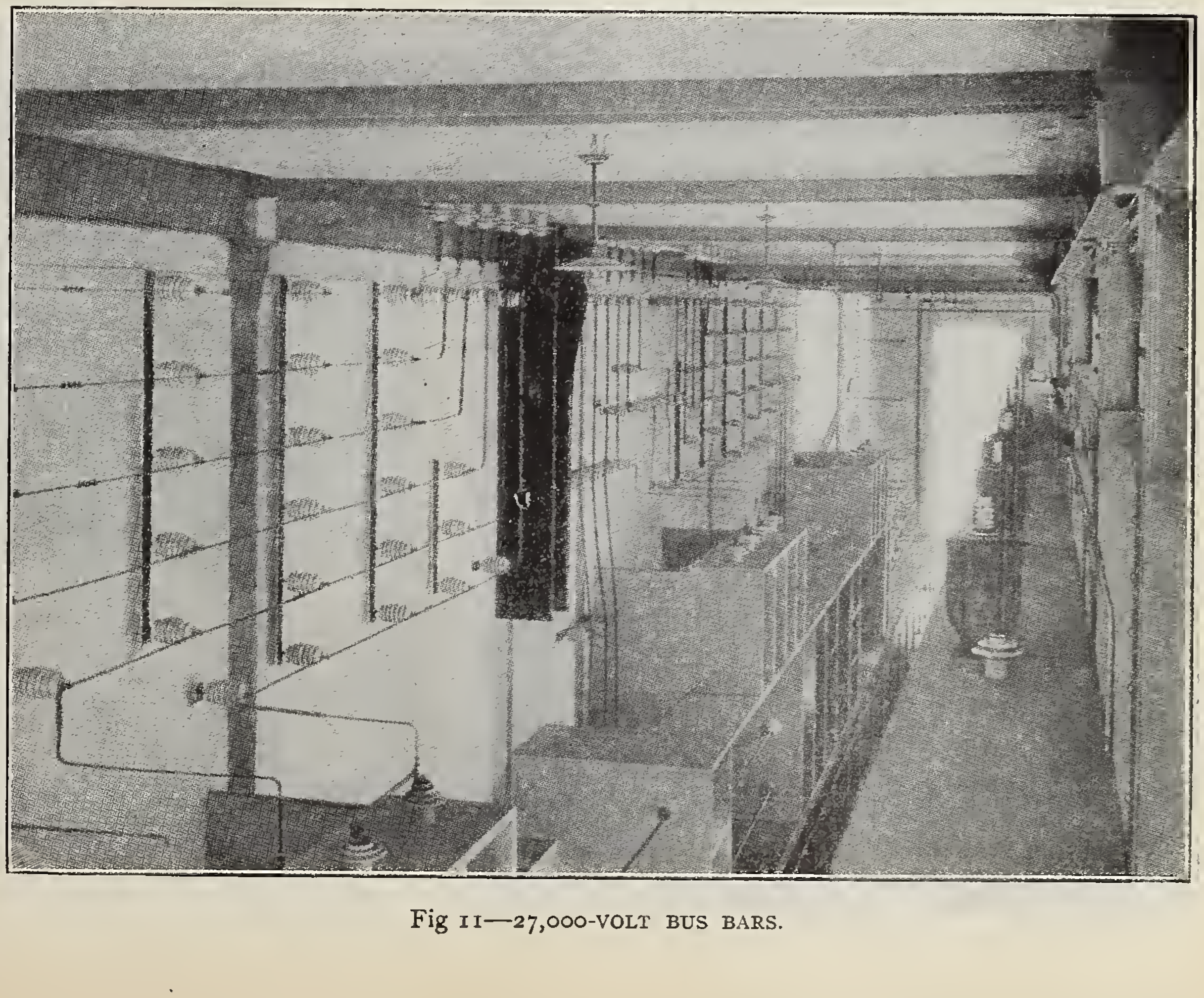


Fig 11—27,000-VOLT BUS BARS.

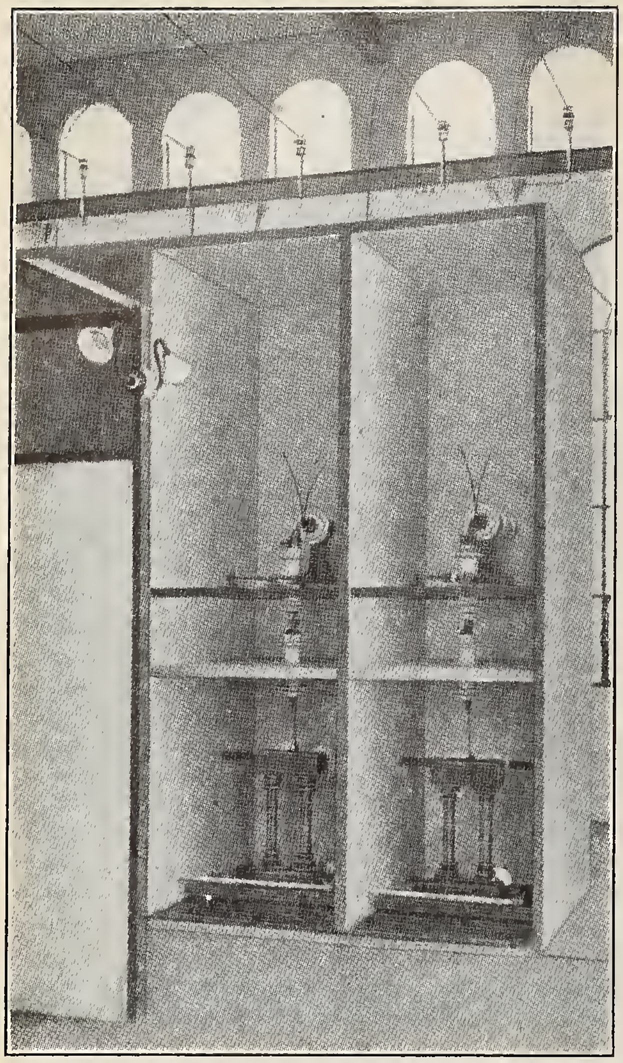


Fig. 12.—HORN ARRESTERS WITH WATER JET DISCHARGERS.

27,000-volt bus bars with the connections that run through the ceiling to the line breakers and protective devices that are located on the floor above. The corrugated pillar insulators for supporting this wiring are typical of European practice for this voltage. The concrete cell work is remarkably well done.

The circuits from the step-up transformers are brought in through the series transformers to the breakers. and the bus on the right-hand side and the ring bus continued around the left-hand side feeds up through the floor to the line breakers which are of the type shown in Fig. 9 and are controlled from the cabinet panels appearing against the left-hand wall at the far end of the operating gallery shown in Fig. 4. The leads that pass up through the floor are connected through a double-throw knife switch to series transformers, then through the oil circuit breakers and choke coils to the outgoing line circuits.

For taking care of lightning discharges, each line is provided with horn lightning arresters having adjustable gaps and liquid resistances as shown in Fig. 12 and water jet dischargers. These arresters have operated frequently since their installation and have given good service in many storms without producing disturbances on the system.

The three high-tension transmission lines from the generating station at Obermatt to the Steghof substation near Lucerne are carried on one set of lattice-work posts, as shown in Fig. 13. The wires are 2 in. in diameter, spaced 40 in. on centers and the poles are normally 200 feet apart, although in some places the distance was increased to 400 feet.

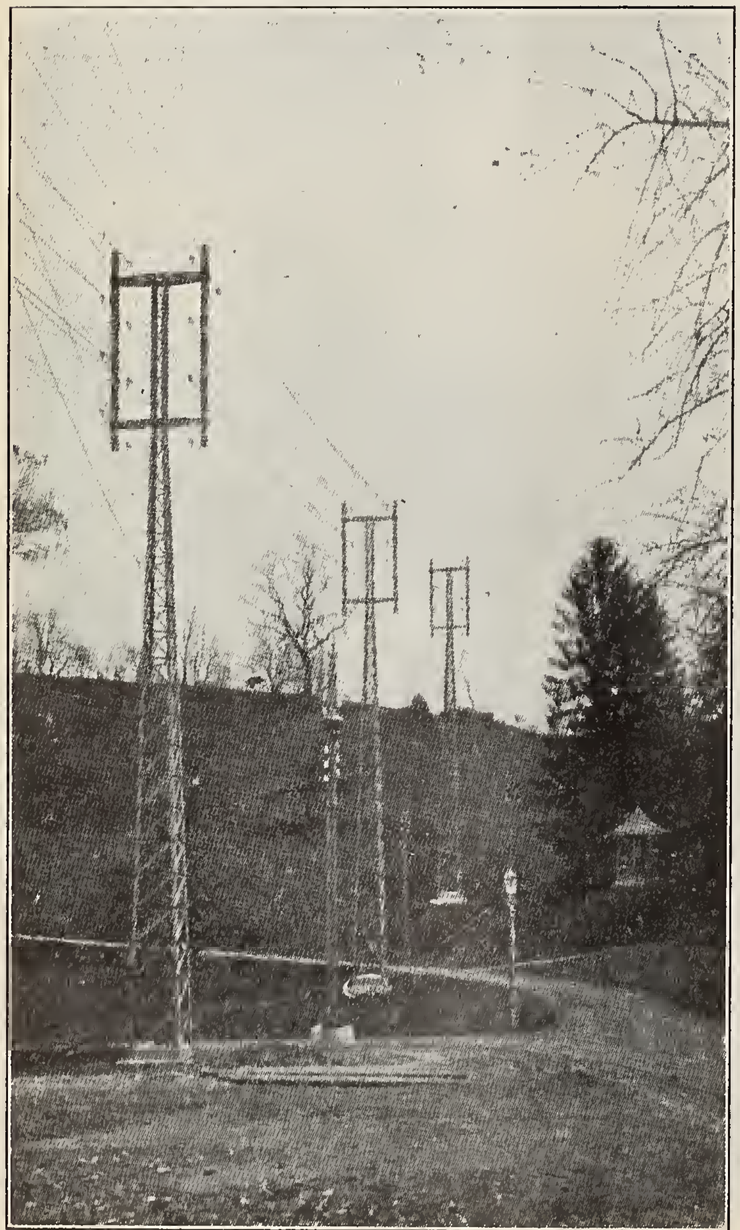


Fig. 13.—HIGH-TENSION LINE NEAR STEGHOF.

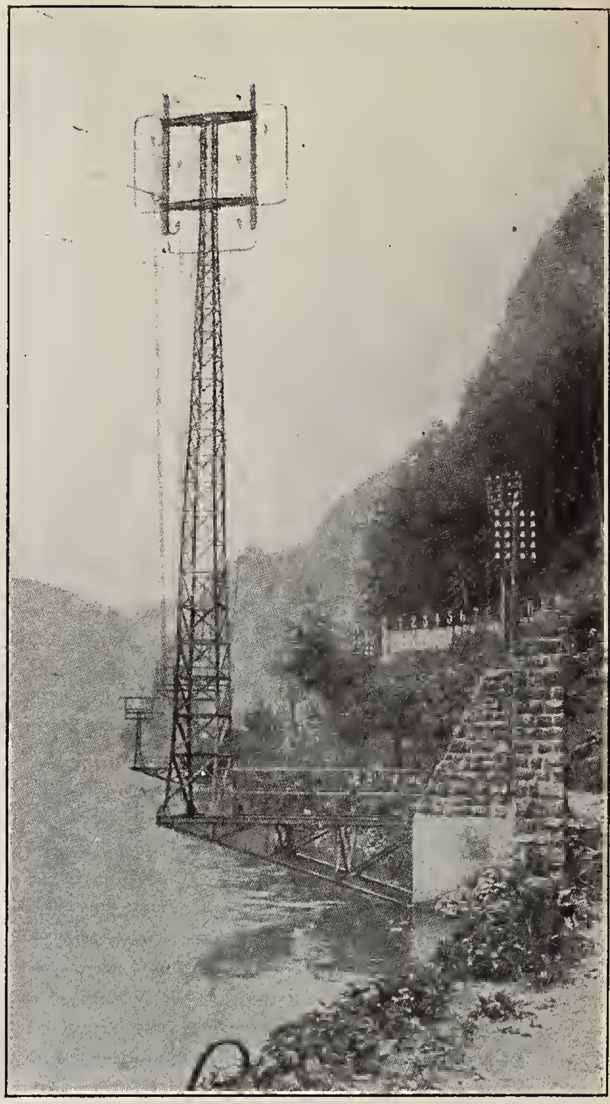


Fig. 14.—HIGH-TENSION LINE AT LAKE LUCERNE.

As may be noticed from the cut, these poles carry two channel iron cross arms to which are fastened uprights of impregnated oak. The insulators are attached to these uprights by curved metal pins of such a shape that the point of the pin is on the same horizontal line as the wire. The standard pole carries 10 insulators, the tenth supporting a copper wire .125 diameter that is connected to the poles and grounded by means of a plate 40 in. square. The posts also carry the telephone line.

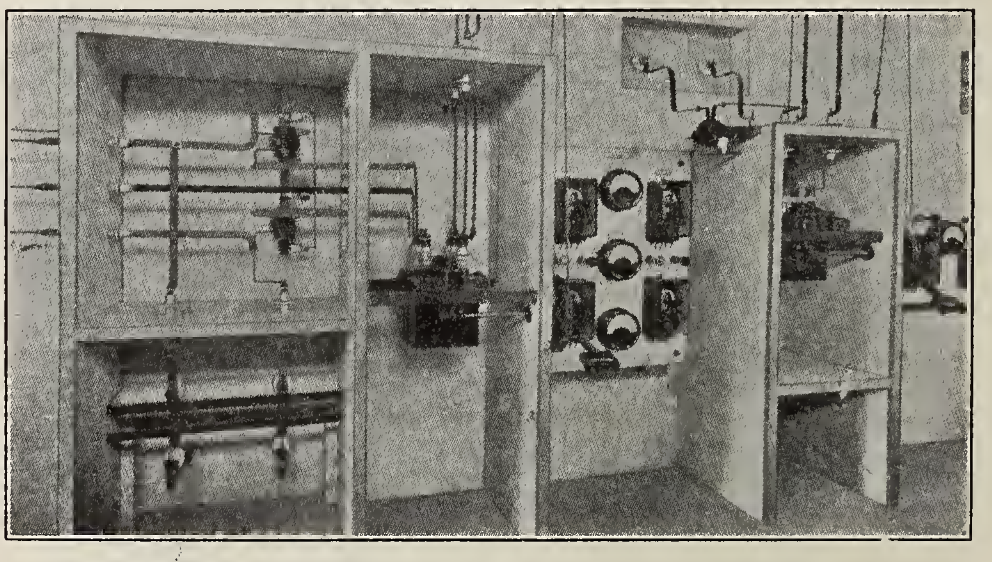


Fig. 15.—TRANSFORMER SWITCHBOARD AT STEGHOF.

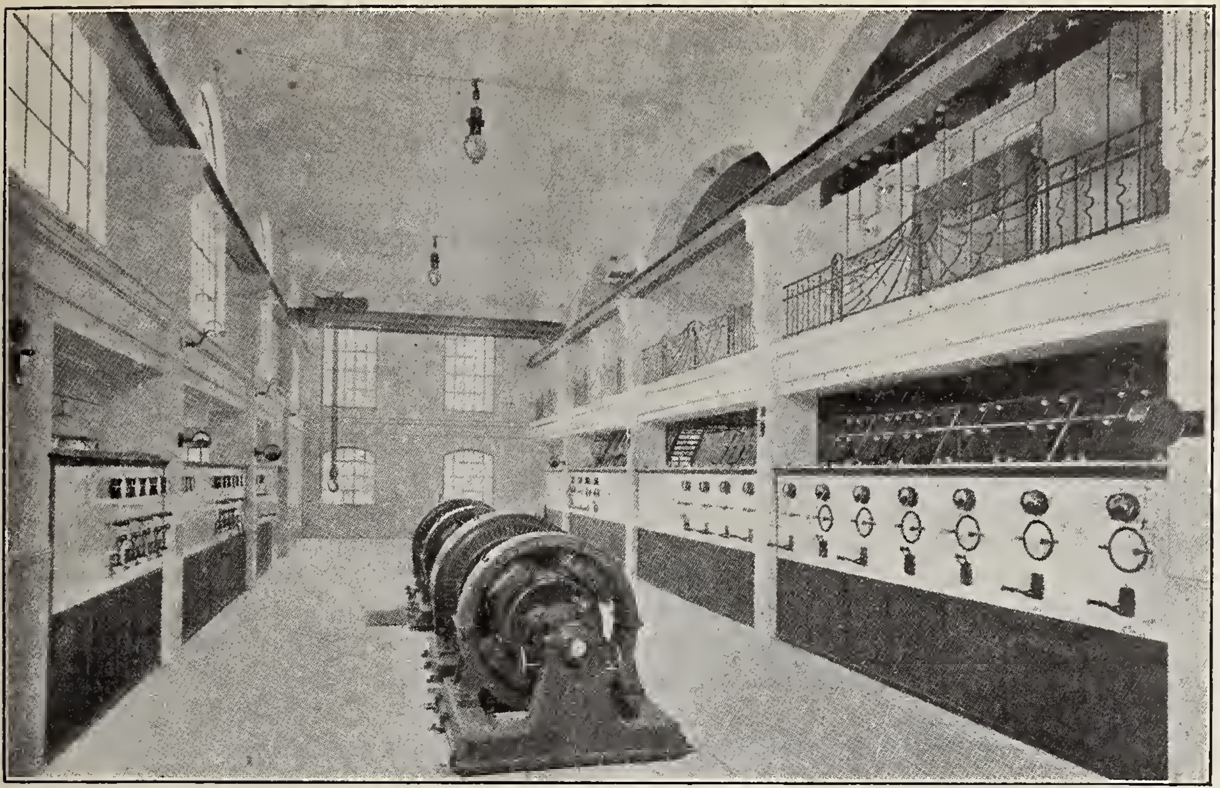


Fig. 16.—STEGHOF SUB-STATION, INTERIOR.

Where the pole line passed along the Lake of Lucerne near the sides of Mount Lopper, a very interesting construction shown in Fig. 14 was made necessary by the depth of the lake, the steepness of the mountain and the presence of the public road with telephone and telegraph lines that could not be disturbed. As may be noted, brackets 18 to 20 ft. long anchored to massive blocks of concrete project out over the lake and carry the poles which are spaced 40 ft. on centers.

The transmission lines pass through three switching stations between the generating station at Obermatt and the receiving station at Steghof, and in these switching stations are installed sectionalizing knife switches and horn lightning arresters with water resistances. The water in these resistances is mixed with glycerin to prevent freezing in winter.

At the Steghof substation there are installed seven 700 k.v.a. transformers stepping down from 24,100 volts to 2650, these being practically duplicates of the step-up transformers shown on Fig. 3. Three of these are used in a delta-connected group for power, three are connected on one phase for lighting and the seventh is a spare for the power circuit.

The high-tension connections and the ring bus bars are arranged similar to the generating station, but the low-tension transformer equipment is somewhat different. As shown on Fig. 15 the low-tension transformer breaker is located in a concrete compartment and the operating rod is provided with a handle and a pulley and rope mechanism for the high-tension breaker.

The relays, ammeters and signal lamps are located on a marble panel between the circuit-breaker compartment.

The low-tension alternating-current feeders are controlled from a separate panel switchboard appearing on the right-hand side of the machine room shown in Fig. 16, the board extending on still further to the right. This switchboard comprises 29 panels of white marble, forming practically a wall along one side of the room, between the columns and the space below the panels is filled with grill work. Beginning at the right-hand end, the first two panels contain a total of five static voltmeters connected between the low-tension three-phase power bus and ground, and the low-tension single-phase lighting bus and ground. The next panels contain the ammeters and signal lamps for the 24,100-volt incoming lines and these are followed by the panels that control the single-phase and three-phase 2650-volt feeders for the lighting and power circuits of Lucerne. Each panel is provided with an ammeter operated by one series transformer and an automatic oil circuit breaker operated by another series transformer for the single-phase circuits or two for the three-phase. On the face of each feeder panel is a diagram of the feeder circuits in Lucerne with the particular feeder controlled by that panel specially marked. Diagrams of connections are posted in conspicuous places, and on these are marked the location of the oil circuit breakers, sectionalizing switches, operating levers, etc.

Back of each panel is a concrete cell containing the overload oil circuit breaker, two or three series transformers and the bell for the outgoing cables. As may be noted, the voltmeters are placed on brackets fastened to the columns and extending out into the station in order to be more readily seen.

There are at present installed two motor-generator sets with provision for a third. Each set comprises a 340-kw., 2650-volt, three-phase induction motor and a 300-kw., 575-volt, direct-current generator running at 490 rev. per min. The induction motors are provided with wound secondaries and the starting resistance is mounted on the shaft of the machines. The direct-current generators are shunt wound and operate in multiple with a battery on a tramway load.

The switchboard for the control of the motor-generator sets and tramway feeders is located along the left-hand side of the room and is divided into three parts. At the far end of the room are the panels for the control of the induction motors containing the overload oil circuit breakers, ammeters and signal lamps. Adjacent panels are separated on the back by concrete barriers and the cells contain the oil breakers, series transformers and the bell for the three conductor cable running to the motors.

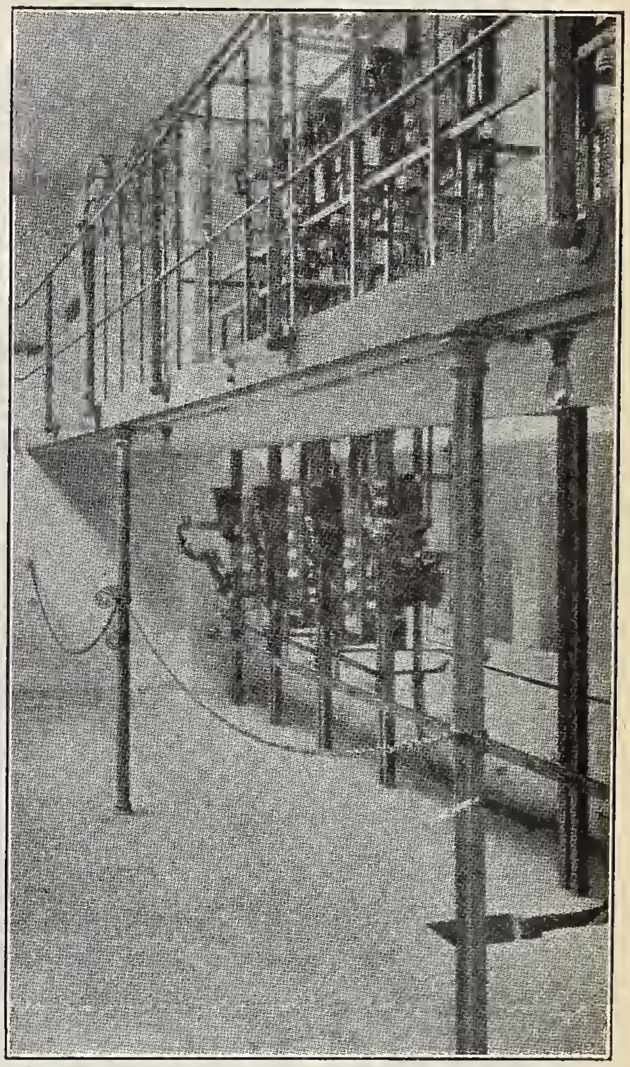


Fig. 17.—DIRECT-CURRENT SWITCHING APPARATUS AT STEGHOF.

The next panels controlling the generators each contain voltmeter, ammeter, underload and overload circuit breaker, field rheostat and signal lamps. The two next panels control the storage battery and contain ammeter, voltmeter, two circuit breakers, signal lamps and the instruments for

measuring the entire load, namely, three ammeters in the ground returns and a recording wattmeter.

The third part nearest the front contains the out-going line panels. Each feeder cable has an ammeter, an overload circuit breaker and two signal lamps. A magnetic interlock is provided that prevents closing a circuit breaker in case the ground on the tramway feeder continues. When the breaker opens, an ohmmeter and a little battery are automatically placed in circuit between the corresponding line and the ground, and in case there is a short circuit this ohmmeter and battery circuit is closed on itself. The normal current through the ohmmeter measures the insulation of the line and at the same time energizes a magnet holding in the interlock on the breaker, and this prevents the breaker from being closed as long as the short circuit exists on the line.

The direct-current apparatus is so arranged as to separate the two polarities completely, as shown in Fig. 17. The negative switch gear is located on the main floor while the positive is in the basement.

When comparing Swiss practice, particularly in reference to the switchgear as illustrated by this plant, with standard American practice the most striking features are the fine concrete work envied by all American engineers, and the elaborateness of detail used in placing the apparatus in compartments and in providing interlocks to insure proper operation of apparatus. The direct-current switch-gear seems remarkably complicated and apparently expensive when compared with an American panel switchboard such as would be supplied for two 300-kw., 550-volt generators. The alternating-current equipment also takes up far more space than would be normally allotted to it in America, and while the oil circuit breakers for a generating station of this size in American practice would be probably provided with separate tanks in independent compartments and be electrically operated and consequently more expensive, it is doubtful whether the total cost, installed, would be as great as the Swiss switchgear and it is certain that the space occupied would be far less.

The Tungsten Lamp Situation in Various Cities

A Symposium, Prepared From Reports Received by the President of the Association of Edison Illuminating Companies

by E. A. BAILY

Probably no one development of recent years affecting the central station industry has given rise to more general interest, or bids fair to produce more revolutionary results, than has the rapid advancement in incandescent lamp manufacture, most notable in the advent of the tungsten lamp.

Since the introduction of this new lighting unit for general commercial purposes some two years ago, its use, though limited at the start, has steadily increased; until at the present day there are but few towns of any consequence throughout this country in which the tungsten lamp is not known and is not being used to some extent.

In the matter of presenting the tungsten lamp situation before this association, it was believed by the president that the convention would be more interested in a symposium showing what use has been made of the tungsten lamps in various cities, and with what results, rather than in a paper offered by any one company or individual.

Accordingly, with the view of presenting a report that would prove characteristic of the situation as it now exists throughout the country, the representative companies of this association were requested to contribute brief articles covering their tungsten lamp experience. In response to this request, reports were received from the companies operating in the cities of Baltimore, Boston, Brooklyn, Buffalo, Chicago, Detroit, Kansas City, Los Angeles, Minneapolis, New Orleans, New York, Philadelphia, Rochester, St. Louis, St. Paul, San Francisco, Spokane, and Washington, D. C.

In the request for information above referred to, no set list of questions was asked, although it was suggested that the following points be covered in making out the reports:

1. The approximate number of tungsten lamps now in service in the territory controlled.

2. The approximate percentage of lamps in service that have been furnished by the company.

3. The size of lamp in most general usage, and the reason therefor.

4. The general effect on revenue resulting from the use of tungsten lamps.

5. The extent to which new business, which was hitherto unobtainable, has been secured by the use of the tungsten lamp.

6. Any special policy plans that may have been pursued to encourage the use of tungsten lamps.

The reports received having followed no particular form, it is impracticable to present any definite tabulated data; but inasmuch as they apply to the outline as suggested, they have been briefly correlated. Following the correlation the papers appear in full, in order that none of the important points may be overlooked.

Although the reports presented relate different experiences and outline various methods of handling the tungsten lamp situation, it is most interesting to note that all seem favorably inclined toward the tungsten lamp, while the majority endorse it heartily as a great boon to both the central station and the consumer.

The 18 companies reporting represent installations totaling considerably over 1,000,000 tungsten lamps. It is a coincidence that the two companies reporting the largest number of these lamps in use should be situated, one on the Pacific, and the other on the Atlantic coast. These, the New York and San Francisco companies, each claim for their circuits 200,000 lamps or over. Both the Chicago and Boston companies fix their estimate at exceeding 150,000, while with the others the number of these lamps in use varies from 3 to 60 thousand.

Of the lamps now in service, by far the greater number have been put out by the central stations, as against the jobbers and electrical contractors. The estimates furnished show that in three cities over 90 per cent. of the tungsten lamps in use have been furnished by the central station. In eight other reports the percentage of company output is given as between 60 and 90 per cent.; while five have furnished but

40 per cent. or under, and with two the field has been left entirely to outside interests.

In the matter as to which style of lamp is most popular with the general public, there is quite a variety of opinion. Based on the reports in hand, the lamp most popular in the largest number of cities is the 40-watt size. The 60-watt size is a close second, followed in turn by the 100-watt and 25-watt sizes. However, it must not be assumed that the last two styles of lamp mentioned above are not being used to good advantage. The Boston and New York companies each report as having more 25-watt lamps on their circuits than any other type, while the Brooklyn and Kansas City companies report in favor of the 100-watt type.

Some of the arguments advanced in favor of the different lamps are given below:

The 40-watt lamp is well liked, as it combines a saving in cost of current consumed and cost on lamp; is nearest in size to the 16 c-p. carbon filament lamp, doubling the candle-power, although using enough less electricity to be appreciably noticed in the monthly statement; and can be easily used in old-style fixtures.

The popularity of the 60-watt lamp is largely due to its adaptability to fixture work, most notable in the cluster type.

The 100-watt lamp is in turn favored by some on account of its being the most economical to install: its satisfactory distribution of illumination and long life.

The 25-watt and 250-watt lamps are used much less extensively than the other types, but appear to be gaining in favor, the latter having been used in several instances to take the place of gas arcs.

In general, it appears that the lamp which is most popular in any territory is the one that is pushed by the central station in that territory. This is evidenced by the fact that in Rochester the company pushed the 100-watt lamp in preference to the 60-watt lamp, which was in popular demand, with the result that there are reported to be about an equal number of both 60- and 100-watt lamps in use in Rochester.

The question as to what is the general effect of the tungsten lamp on revenue must, of course, for purposes of comparison, apply to old customers only and leave out of consideration the great amount of new business now available, which it was hitherto impossible to obtain.

There is such a variety of opinion on this subject as to make a fair summary difficult. The reports where given are only for a certain number of cases taken at random and averaged, and show percentages ranging from 20 per cent. increase to 40 per cent. decrease. Another handicap in arriving at a conservative figure lies in the fact that in many instances where the lamp is used the installation is only partial, and in others has been in use but for a short time.

From the reports in hand the majority sentiment seems to be that the tungsten lamp will not permanently decrease revenue, even from existing customers, for, although the primary effect has been to cause a noticeable decrease in both connected load and in revenue, the continued usage has resulted in a gradual increase which eventually exceeds in point of revenue the figure formerly attained. Whether or not the new business will more than make up for any decrease among existing customers depends upon the energy of the sales department.

If in no other way, the tungsten lamp has proved its merit in making it possible to secure business that was hitherto unobtainable. All but six of the companies reporting have found the tungsten lamp to be of great assistance in this respect. Of these six companies, two, the San Francisco and Rochester companies, control both the gas and electric business in their respective territories. Another, the Spokane company, presents a unique situation. This company reports of having absorbed practically all of the available business, such as the displacing of gas, by the use of Gem and meridian lamps before the tungsten lamp became a commercial possibility.

Many straight gas installations have been superseded by the tungsten lamp, most notably in the case of small stores, where electricity under old conditions was looked upon by the proprietors as a luxury beyond their means. The Brooklyn company reports of having obtained over 1500 new customers, who were formerly exclusive users of gas, while the Boston company has placed 30,000 lamps under similar conditions. The Minneapolis company has been successful in obtaining municipal street lighting, and in several cases the tungsten cluster has proved successful, the Chicago company having installed between six and seven thousand, which net an annual revenue of $250,000.

However, the success of the tungsten lamp has not all come of itself, but is due in a large measure to the energetic and continued pushing by the central station companies. Advertising, both of the "direct to customer" and "educational" variety, in the newspapers, cars, etc., has been indulged in liberally and with good success.

The sales departments, too, have laid special stress on the introduction of the lamp, and in several cases the regular force has been augmented by the employment of special tungsten lamp solicitors, who have devoted their entire time to the work.

With the Brooklyn and Detroit companies, the work of introducing tungsten lamps was considered so important that subsidiary companies were formed to deal exclusively with the situation. The Brooklyn organization, known as The Tungsten Lamp Specialty Company, was launched in March, 1908, with a soliciting force of its own, which is now paid on a commission basis only. This company, up to Aug. 15, 1909, had secured contracts to the number of 1254 from persons 95 per cent. of whom were formerly exclusive users of gas. Practically all of the wiring is sublet to contractors, who do the work at a fixed price per outlet, the company furnishing appropriate glassware, lamps and fixtures. In passing, it may be stated that the details of this organization were clearly outlined in the paper entitled, "A Self-Supporting Tungsten Lamp Campaign," presented at the Lenox Convention, 1908.

The Detroit company, in order to control the tungsten lamp situation, organized a company for the purpose of selling tungsten lamps and fixtures. This company sold its merchandise at a price sufficient to make it self-sustaining, and made a low price on renewals of lamps purchased from them, so that they secured practically all the central station tungsten business. Although organized in the middle of October, 1908, up to the first of this year this company did no soliciting, owing to the volume of work that came to them voluntarily, which was more than could be handled. Early in January both the tungsten and illuminating companies put solicitors in the field, and up to the 15th of June had replaced 650 gas arcs, innumerable single gas burners and had secured other new business from gas users from which it is estimated an annual income of $16,000 will be derived.

The companies operating in Chicago, Kansas City and Philadelphia have instituted rental propositions which are worthy of special note. The Chicago company, for over a year, has offered a four-lamp cluster containing either 40- or 60-watt lamps, installed and wired free, requiring that the customer contract to use the fixture for a period of at least two years, either at a flat rate per week, covering fixed hours' daily use, the electricity being turned on and off by the company's representatives; or, in consideration of the payment of a monthly rental, covering the use of the cluster and the renewal of lamps, that the

electricity be paid for in addition to this amount, at regular rates. The rental under this latter proposition, formerly $1.50 per month, is now $1.00 per month, permitting three hours' daily use. These clusters are placed on a separate meter and, if it is found that the lamps are used more than three hours daily, a charge of 20 cents per hour, per day average per month, is exacted to cover the cost of lamp renewals.

The rental proposition of the Kansas City company consists of a two-year contract, whereby the consumer agrees to use electricity exclusively for lighting, and the company in turn furnishes either a one, two, three or four light fixture as desired. These fixtures are equipped with 100-watt tungsten lamps, for which the consumer agrees to pay a monthly rental charge at the following rates: First lamp to be 50 cents per month; the second, 40 cents per month; the third, 35 cents per month; and all in excess of three, 25 cents per month.

The Philadelphia company supply a two or three 100-watt tungsten fixture on a monthly rental and cost basis at the rate of $1.25 per month for the two-lamp fixture, and $1.75 per month for the three-lamp fixture. The consumer agrees to pay rental and maintenance charges on the same day as bills for current are rendered under the lighting contract. At the end of one year the consumer becomes the owner of the fixture, which, if desired, the company maintains at a cost of 50 cents per month in the case of the two-lamp fixture, and 75 cents per month for the three-lamp fixture.

Somewhat in line with the three policies outlined above, the Rochester company has introduced a maintenance proposition, which is meeting with much success. This consists of making four inspections per month, and in addition to renewing blackened and burned-out lamps, to keeping the glassware in good condition, washing and cleaning the same when necessary. The rates for this service, which it is claimed is doing more to encourage the use of tungsten lamps than any one scheme yet adopted in Rochester, are as follows:

On 40-, 60- and 100-watt lamps, installation of eight lamps or over, eight cents per lamp per month; for installations of less than eight lamps, 10 cents per lamp per month; for 250-watt lamps, 10 cents per month.

In certain difficult cases a customer has been secured by means of installing a fixture or two temporarily, the effect of which has proved so attractive that an order for a complete equipment has been the result. Still again, the manufacturers have co-operated by placing representatives in the field to work in conjunction with the local sales department.

The general conclusion that may be drawn from the reports presented is that the tungsten lamp, if correctly handled, is a benefit to both consumer and central station—to the former on account of its great efficiency and consequent reduction in current charge, and to the latter from the field for new business which it has opened up.

With the foregoing brief remarks, the reports that follow are commended for your consideration:

REPORT OF CONSOLIDATED GAS, ELECTRIC LIGHT AND POWER COMPANY OF BALTIMORE, BALTIMORE, MD.

There are approximately 50,000 tungsten lamps in use on our lines, of which number 80 per cent. have been sold by this company. About 40 per cent. of our output has been the 40-watt size. The reason for the popularity of this size is no doubt in the fact that it is the cheapest lamp and gives increased lighting as compared with the usual carbon lamps without changes in fixtures, customers generally wanting to use the same outlets and reflectors for tungsten lamps as were used for carbon lamps, to avoid the expense of new or additional equipment. The selling price of 25- and 40-watt lamps has been the same. Prices of tungsten lamps, as of May 1st, are given below:

Lamps.	Candle Power.	Plain.	Frosted Tip or All Frosted.
25 watts	20	$0.60 each.	$0.65 each.
40 "	32	.60 "	.65 "
60 "	48	.95 "	1.00 "
100 "	80	1.15 "	1.20 "
250 "	200	2.30 "	2.40 "

Tungsten lamps are replaced at the company's expense is accidentally broken and returned within 48 hr., or if showing defects in manufacture and returned within 30 days.

When tungsten lamps were introduced we made a special canvass of our customers, our representatives offering suggestions freely as to proper lamps and reflectors to be used. The company advertised extensively on bills, electric signs, in special pamphlets and newspapers. We have been able to light a great many places of business with tungsten lamps in a more satisfactory and economical manner, due attention being given to usefulness and quality of light.

The introduction of tungsten lamps has been parallel with the standardization of rates after a rate war, and it is difficult to get a number of cases for comparison which are not complicated with some change in price or rearrangement of lighting units. Takking, however, 28 random cases of customers still on war rates, the use of tungsten lamps has reduced the consumption by 23,314 kw-hr. from 175,728 kw-hr., or 13 per cent.; and taking 15 cases of customers on standard rates, both last year and this year, the decrease has been 1512 kw-hr. on 10,179 kw-hr., or about 15 per cent.

We have been unable as yet to obtain new busines to any considerable degree with tungsten lamps which was hitherto unobtainable, though we believe that the tungsten lamp will in future be of assistance to us in securing new business.

REPORT OF THE EDISON ELECTRIC ILLUMINATING COMPANY OF BOSTON, BOSTON, MASS.

The Edison Electric Illuminating Company of Boston has, from the earliest introduction of the tungsten lamp on a commercial basis, consistently and persistently pushed its introduction among the customers served by its lines in the City of Boston and its suburbs. It has, however, endeavored to avoid their too rapid introduction, such as would result in a serious reduction in its income.

The methods employed in calling the public's attention has been through letters addressed to each customer, through liberal newspaper advertising and through the efforts of the various members of the sales department in personal interviews.

The lamps are supplied by the company to its customers at special prices, which are less than the market prices, as follows:

25 watt, plain or frosted	$0.60
40 " " " "	0.75
60 " " " "	0.90
100 " " " "	1.10
250 " " " "	3.00

The lamps are delivered almost entirely by special delivery men, carrying them in fibre cases especially made for the purpose. In some of the suburban districts orders have been delivered by our regular lamp delivery wagon.

The lamps are installed in the sockets and found to be in operating condition before our men leave them.

If lamps are delivered at the lamp room to a customer, upon his request, they are first tested in his presence to establish with him that they are in operating condition, and all risk is then assumed by the customer.

Our figures on breakage have not, on the whole, been very great. In transportation from the manufacturer it has amounted to one per cent.; from our lamp department to the consumer, placed in sockets, three per cent.; and breakage that has been allowed to customers, two and one-half per cent; making a total of six and one-half per cent.

Our early burnouts have amounted to three per cent. in the 100-watt, one and one-half per cent. in the 60-watt, two and one-half per cent. in the 40-watt and three per cent. in the 25-watt

sizes, making an average of 3%.

We have experienced considerable trouble from the early blackening of the bulbs of the 100-watt lamp, but have had very little complaint from this cause with the other sizes.

We have no means of knowing the amount of income directly due to tungsten installations, or the total number of tungsten lamps on our system, as a large number of lamps have been sold by supply dealers.

We think, however, the immediate effect of their use has been to decrease our income slightly, but that at the end of one year of their use this condition will be reversed and our income will then show a slight increase, and the result of, say, five years' use of tungsten lamps will show a very considerable increase in income.

Of the total number of lamps installed by the company, approximately 30 per cent. have gone into places so that the customer gets little more light than before, but have reduced the sale of electricity; approximately 30 per cent. have gone into places so that the customer keeps the income the same as formerly, but receives considerably more light; approximately 30 per cent. have replaced gas or other open-flame illuminants, and approximately 10 per cent. have gone into new business.

There are probably 150,000 tungsten lamps in use by our customers, and about 100,000 have been supplied directly by the company. Of this 100,000 about 38,000 have been of the 25-watt size, and next in popularity is the 100-watt size.

REPORT OF EDISON ELECTRIC ILLUMINATING COMPANY OF BROOKLYN, BROOKLYN, N. Y.

We have approximately 57,000 tungsten lamps on our service lines at the present time; 75 per cent. of these have been furnished by the company, and the remaining 25 per cent. by the electrical contractors and lamp manufacturing companies.

The lamp that is in general use is the 100-watt lamp. The reason for this is that we have pushed it, and also because it is the most economical to install and gives a more satisfactory distribution of illumination.

It is rather a difficult matter to give the general effect of our revenue covering the number of lamps installed, as several of our customers have made partial installations, but we have selected a list of 64 who have made entire change of equipment from carbon to tungsten lamps, and herewith show the figures for six months, from May to October, 1907-1908, inclusive:

Revenue, May to October, 1907, inclusive	$14,064.42
Revenue, May to October, 1908, inclusive	11,656.78
A decrease in revenue of 21 per cent.	

We have been able to secure considerable new business by the use of the tungsten lamp in premises that appeared heretofore unattainable, due to the economical operation of the lamp, and also due to the fact that we have made special efforts among gas consumers in the past year.

The present policy for handling tungsten lamps is through a subsidiary company known as the Tungsten Lamp Specialty Company, which has a soliciting force of its own, which are paid on a commission basis for all business secured. These solicitors work in co-operation with the solicitors of the Edison Company, and through their combined efforts we have been able to secure over 1500 contracts for tungsten equipments in premises which were heretofore burning gas exclusively.

In addition to the above, the Edison Company calls the attention of its customers to the tungsten lamp through advertising and by special solicitors who concentrate on present customers, calling their attention to the advantages of a tungsten equipment, the object being to secure the entire business of the consumer with the tungsten lamp, and our efforts in this direction have been very encouraging thus far, as we have inquiries every day from our present customers.

A feature of this campaign which is well worth mentioning is that we present to the customer we have succeeded in interesting a blue print of his store, showing the layout of an entire tungsten equipment, giving him figures and comparison to his present consumption plus his gas bill, showing thereby that, with this type of equipment, he can save money and secure better illumination.

The following is price list of tungsten lamps, as sold to our customers:

	To free renewal customers	To other customers
250 watts, 200 candle power..	$1.75	$2.25
100 watts, 80 candle power..	.90	1.15
60 watts, 48 candle power..	.75	.90
40 watts, 32 candle power..	.60	.70
25 watts, 20 candle power..	.50	60

The above lamps are kept in stock and promptly delivered on written order. No additional charge is made for frosted tip lamps.

THE FOLLOWING TABLES SHOW THE DETAILS FROM INTRODUCTION TO JULY 1, 1909.														
TUNGSTEN LAMPS FOR INSTALLATIONS.	250 W.		100 W.		60 W.		40 W.		SMALL BULB 40 W.		25 W.			
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%.
LAMPS ORDERED.														
LAMPS RECEIVED.														
LAMPS USED.	27		11782		7513		3895		1205		5678			
BROKEN FILAMENTS														
DUE TO HANDLING.			516	4.4	506	7.0	627	16.0	25	2.0	290	5.1		
DUE TO EARLY BURNOUTS														
PERCENTAGE BROKEN.														
TUNGSTEN LAMPS FOR RENEWALS.														
LAMPS ORDERED.														
LAMPS RECEIVED.														
LAMPS USED.	22		10900		8660		11618		2315		31728			
BROKEN FILAMENTS.														
DUE TO HANDLING.	1	4.6.	221	2.0	243	2.8	726	6.2	79	3.4	415	1.3		
DUE TO EARLY BURNOUTS			635	5.8	275	3.2	413	3.5	20	0.9	1154	3.6		
PERCENTAGE BROKEN.	1	4.5	856	7.8	518	6.0	1139	9.7	99	4.3	1569	4.9		
TOTALS.														
LAMPS ORDERED.	84		28080		19512		17012		14500		51100		130288	
LAMPS RECEIVED.	84		26377		18562		16864		11200		50800		123887.	
LAMPS USED.	49		22682		16173		15513		3520		37406		95343	
BROKEN FILAMENTS.														
DUE TO HANDLING	1	2.0	736	3.2	749	4.6	1353	8.7	104	3.0	705	1.9	3648	3.82
DUE TO EARLY BURNOUTS			635	2.8	275	1.7	413	2.7	20	0.5	1154	3.1	2497	2.62
PERCENTAGE BROKEN.	1	2.0	1371	6.0	1024	6.3	1766	11.4	124	3.5	1859	5.0	6145	6.44

TUNGSTEN LAMP RECORD OF THE EDISON ELECTRIC ILLUMINATION COMPANY OF BOSTON.

REPORT OF BUFFALO GENERAL ELECTRIC COMPANY, BUFFALO, N. Y.

The Buffalo General Electric Company has conducted an aggressive tungsten lamp campaign since June, 1908.

It is estimated that there are 25,000 tungsten lamps connected to the company's system; 40 per cent. of this number have been sold to the consumer by this company. The lamp in most general use is the 40-watt small bulb.

We believe that in the smaller size tungsten lamps the small bulb 40-watt unit is the one to be pushed, not only from the standpoint of the central station, but of the consumer as well. Contrasting the 40-watt with the 25-watt unit, it appears that, due to the greater mechanical strength and increased cross-section of the filament

of the 40-watt lamps, we obtain an average life which is from 30 to 50 per cent. greater than that of the 25-watt lamp. This fact, together with the superior candle-power, has brought us to the conclusion that it is better suited to the requirements of our consumers, and that it is far superior to the 25-watt lamp, both from their standpoint and our own. The majority of complaints of breakage from our consumers are from users of the 25-watt lamp. This is due to the fact that these lamps break more easily when dusted; or when the snap-switch is turned off with a sharp quick jar the lamp is broken, and the next time the consumer turns it on, it is what he terms "burnt out," and if it has been in use but a short time he calls on the company to give him a new lamp, which, of course, in the majority of cases is out of the question.

It is the policy of the company in selling tungsten lamps to have them delivered to the consumer's premises by a competent representative and tested, after which time the company assumes no responsibility whatever for breakages. The advisability of this plan is shown by the fact that during a period of six months the renewals supplied by this company on account of accident, imperfect lamps or otherwise, amounted to only two and one-half per cent. of the total number of lamps sold during that period.

To avoid the use of the 25-watt lamp, we are selling both the 25 and 40-watt lamps at the same price, 70 cents.

Of the total number of tungsten lamps sold by this company during the past year, 40 per cent. were 40-watt lamps. We believe that during the coming year the percentage will be even greater.

In regard to the larger tungsten units, we give preference to the 250-watt frosted bowl lamp.

Our experience with this lamp shows that it has a remarkably long life, somewhere between 1500 and 2000 hours. We have replaced innumerable four and five light clusters of 16 c-p. carbon lamps with this unit, to the expressed satisfaction of the consumer.

In dealing with electric arc lamp installation we have often installed two 250-watt lamps for each arc lamp replaced, giving the consumer much better illumination. We have fewer complaints and more expressed satisfaction from this unit than from any other.

The tungsten lamp, and particularly the 250-watt unit, has been very successfully used in meeting gas competition. Natural gas is used quite extensively for illumination and is sold at 30 cents per thousand cubic feet; manufactured gas is sold at $1.00 per thousand cubic feet. We are able to meet competition from manufactured gas without very much trouble, but natural gas, of course, is a great source of trouble. The 250-watt unit has replaced a large number of gas arcs using natural gas. This is especially so in small stores using electricity for window lighting and gas arcs in the interior.

As to the general effect on our revenue resulting from the use of tungsten lamps, we submit the following figures based upon 25 of our consumers who formerly used carbon filament lamps and are now using tungsten lamps. These installations vary from 150 watts to 3000 watts in tungsten lamps:

Entire connected load in 50 watt equivalent	3,320
Total tungsten installation, 50 watt equivalent	370
Kw. H. consumption for May, 1908, when carbon filament lamps were used	10,390
Kw. H. consumption for May, 1909, when tungsten lamps were used	8,986
Total income for May, 1908	$548
Total income for May, 1909	$512
Rate per Kw. H. obtained in 1908	5.28c.
Rate per Kw. H. obtained in 1909	5.7c.
Decrease in revenue	$36
or	6.6%

We sell all tungsten lamps to our consumers at 20 per cent. off list, with the exception of the 40-watt lamp, which we sell at the same price as the 25-watt lamp. We have one man who devotes all his time to the demonstration of tungsten lamps.

REPORT OF COMMONWEALTH EDISON COMPANY, CHICAGO, ILL.

As near as we can estimate, there are approximately 150,000 tungsten lamps now on our circuits in Chicago. In addition to this there are possibly 10,000 to 20,000 in use by the isolated plants, although this last is a very loose estimate, as we have no way to get very exact information.

Of the number of lamps on the circuits of the Commonwealth Edison Company, about 100,000 have been furnished by this company, as follows:

60 watt lamps	50,000
40 " "	30,000
25 " "	18,000
100 " "	2,000

In some individual cases which have come to our attention the result of the use of these lamps has been a reduction in the bills, and in others the consumption has been as large or larger because people seem to desire more light for the same money rather than the same light for less money.

On the whole, we are satisfied that the use of tungstens has not decreased our income from existing customers. On the other hand, the new business which it has been possible to obtain as a result of the use of these lamps has afforded substantial increase to our revenue. The particular use of them by this company has been the obtaining of customers among the smaller stores and shops where other than electrical illumination has previously been used.

For somewhat over a year we have been offering a standard four-lamp cluster containing 60 or 40-watt lamps at the election of the customers, installed and wired free, making the customer contract to use the fixture for a period of at least two years, either at a flat rate per week, covering certain fixed hours of daily use, the electricity being turned off and on by the company's representatives, or in consideration of the payment of a monthly rental covering the use of the cluster and the renewal of lamps, the electricity being charged for in addition to this amount in regular rates. The rental under this latter proposition was originally $1.50 per month, permitting four hours' use of the lamp, but this has been reduced to $1.00 per month, permitting three hours' daily use. These clusters are placed on a separate meter and if from its indication it is found that the lamps are used longer than three hours daily, an additional charge of 20 cents per hour, per day average per month, is charged to cover the extra cost of lamp renewals. The meter proposition seems to be much the more popular of the two.

This company has installed between 5000 and 6000 of these clusters and derives from them an income of approximately $250,000 per annum.

In renewing lamps to our central station customers who would be entitled to carbon lamp renewals free of cost the following special prices have been used:

25 watt	55c
40 "	60c
60 "	70c
100 "	85c

the idea being to compensate in the price for the carbon lamp which otherwise would have been furnished free. If, however, the customer prefers to purchase his own lamps the company offers generally to put him on a basis where he can provide all lamps used in his installation at a reduction of one-half cent per kilowatt-hour.

While the company does not urge particularly the use of 25-watt lamps it does not make the slightest objection to furnishing them to the customer if desired and is convinced that its policy in this respect will not generally affect the income.

REPORT OF THE EDISON ILLUMINATING COMPANY OF DETROIT, DETROIT, MICH.

In Detroit the central station company does no construction or supply business and it was not considered advisable to change this policy to meet the conditions arising from the tung-

sten lamp development; at the same time, we wished to control the situation and in order to do so a company was organized to sell tungsten lamps and fixtures. This company sold their merchandise on a margin of profit sufficient to make the company self-sustaining, and made a low price on renewals of the lamps purchased from them, which brought practically all the tungsten business of central station customers to this company.

The company was organized in the middle of October and up to the first of the year did no field work, as the volume of business coming unsolicited from the retail merchants in the down-town district was more than the new organization could handle. During November and December some twenty-five large installations were changed to tungsten lamps, replacing, in most cases, electric arc lamps.

In analyzing the accounts of these customers we find that on a comparison with six months of tungsten service against the corresponding six months of the previous year the bills show a decrease in revenue of about $1,300 and we have saved in arc lamp maintenance and carbon lamp renewals about $650 on the same service. These accounts run from $25 to $250 per month and a number are listed herewith showing the difference in income from the tungsten and the former installations:

Business.	Av. Bill on 6 Mos. Service. Arc and Carbon Lamp Installation.	Av. Bill on 6 Mos. Service, Tungsten Installations.
Jeweler	$46.00	$58.00
Dry Goods	179.00	170.00
Clothing	179.00	183.00
Clothing	53.00	34.00
Cigar	69.00	39.00
Jeweler	137.00	88.00
Grocer	64.00	33.00
Book	39.00	34.00
Restaurant	46.00	38.00
5 and 10c. Store	190.00	138.00
Clothier	270.00	195.00
Clothier	105.00	74.00
Women's Wear	60.00	53.00
Clothier	46.00	26.00
Dry Goods	229.00	204.00
Saloon	76.00	59.00
Drug Store	50.00	49.00
Jeweler	62.00	55.00
Jeweler	35.00	25.00

In our early experience with the tungsten lamp we found that every customer considering installations was determined to reduce his cost of current about 50 per cent. by changing to the new style of lamp. Although wishing to avoid serious decrease in our revenues we thought it best to let the customer work out his own salvation in this matter and while strongly recommending a higher standard of lighting our salesmen were instructed to give advice to customers as to the most economical installations possible. Guarantees on unexpired contracts were readjusted to meet the changes in installations and our tungsten lamp company gave the customer an opportunity to buy his fixtures and lamps at a low price. This policy has reacted to our decided advantage and the majority of customers have gradually raised their standard of lighting; have replaced gas in storerooms, workrooms, basements, etc., with electricity, and the bills of the customers who six months ago were concerned chiefly in lighting their stores at the lowest possible cost have increased by degrees until most of them are now paying us monthly bills equal, if not exceeding, their former bills for service, and in retail establishments where formerly two-foot candles were considered good lighting four-foot candles are now the standard of illumination.

Early in January our soliciting force began in earnest to fight gas with the tungsten lamp and our tungsten lamp company put salesmen in the field at the same time. Up to the fifteenth of June we had replaced 650 gas arcs and innumerable single gas burners and had secured new business from short-hour burners that had previously been hard to write because of the difference in cost between electricity and gas. From this new business and that secured from the gas users we estimate an annual income of approximately $16,000.

According to our records we have now in service the following tungsten lamps, sold by our lamp company:

25 Watt	40 Watt	60 Watt	100 Watt
967	1,511	29,996	770

There are possibly some thousand more lamps in use by our customers that have been bought elsewhere and of which we have no record.

In introducing the lamp where gas has been used or in soliciting new business we usually recommend the 60-watt lamp for use in clusters and the 100-watt lamp where single drops are installed. In the down-town district many of the installations are now substituting 100-watt lamps for the 60-watt lamp.

REPORT OF KANSAS CITY ELECTRIC LIGHT COMPANY, KANSAS CITY, MO.

In reply to question No. 1 will say that the approximate number of tungsten lamps now in service in Kansas City is about 21,000.

No. 2. About 60 per cent. of this number was furnished by the Kansas City Electric Light Company.

No. 3. About 70 per cent. of the tungsten lamps in use in Kansas City are 100-watt lamps.

No. 4. We have no data.

No. 5. We have found the tungsten lamp to be of great assistance in obtaining new business. We recently obtained a contract from a business house that has been in business 1[illegible] years, who never used electricity and could not be induced to use it until we approached them on the subject of installing tungsten lamps.

No. 6. We have four solicitors who work tungsten business exclusively. These solicitors devote their time to large business houses whose consumption of electricity is small and to the small consumer who is not using electricity.

We have a rental proposition which we offer as follows:

The contract to be a two-year contract, and consumer agrees to use electricity exclusively for lighting; the light company furnishes the fixtures, the consumer having a choice of one, two, three or four light tungsten fixtures. These fixtures are equipped with 100-wattt tungsten lamps. Consumer agrees to pay monthly rental charge on the equipment at the following rates:

First lamp to be 50c. per month.
Second " " " 40c. " "
Third " " " 35c. " "
All lamps in excess of three, 25c. per month.

REPORT OF THE EDISON ELECTRIC COMPANY, LOS ANGELES, CAL.

The number of tungsten lamps installed in the city of Los Angeles is estimated at 40,000. Of these, less than 500 have been furnished by The Edison Electric Company, or about one per cent. of the total. When the tungsten lamp was first placed on the market, we did not feel that it was in that finished state that justified us in unequivocally recommending its purchase. It was very fragile, and sometimes became quite blackened upon slight use. It also materially decreased the consumption, while largely increasing the lamp costs, and in addition necessitated an expense of from $1.00 to $1.50 per lamp for special shades and fixtures. All this inclined us to the belief that it would be well to let the dealer be the one to introduce the lamp, and stand back of the sales.

The new 40-watt lamp, with its tougher filament, that fits the old shades and burns in any position, has overcome to a considerable extent the above objections. The 40-watt lamp is the one usually sold, being the nearest in size to the popular 16-c-p. carbon filament lamp, doubling the candle power, although using enough less electricity to be appreciably noticed in the monthly statement.

In the majority of residence installations, the tungstens are mixed with the carbon filament lamps, often as an experiment, but even this moderate use has the effect of reducing the revenue. The average consumer has long ago adjusted his illumination to accord with his purse, and while he would like more light, he feels that

the present bills represent about the amount he is willing to pay for lighting. He therefore compromises by using a tungsten installation sufficient to materially increase the illumination and at the same time decrease the consumption.

As the lamp costs are lowered, the income will probably increase until, with the cost of a 40-watt lamp running from 30 cents to 40 cents, it will be larger per meter installed than with the present carbon filament. We have several business houses where tungstens are used as window lights only, and find that in nearly every one the wiring was rearranged to get more light, leaving the consumption about the same.

The following are not selected instances, but are given as fair illustrations of how the tungsten lamp has affected our income from business lighting:

Carbon lamps, October, 1907, to March, 1908, inclusive.

Tungsten lamps, October, 1908, to March, 1909, inclusive.

	Tungsten.	Carbon.	Increase.	Decrease.
1. Pharmacy. Due to arrangement of lighting and increase in business.	$294.00	$211.85	$82.15	
2. Racquet Store. Not all tungstens.	769.25	675.95	93.30	
3. Glassware. All tungstens.	1,523.95	2,231.45		$707.50
4. Dry Goods. All tungstens.	412.65	490.50		77.85
5. Haberdasher. All tungstens.	627.05	684.15		57.10
6. Music House. Part tungstens.	973.90	943.65	30.25	
7. Haberdasher. Part tungstens.	134.10	100.30	33.80	
8. Saloon. All tungstens.	471.30	652.80	181.50	
9. Drugs.	114.20	110.90	3.30	
10. Hatter. Part tungstens; wiring rearranged.	393.45	375.45	18.00	
Totals.	$5,713.85	$6,477.00	$260.80	$1,023.95
			Loss. .	$763.15

We have obtained very little new business through the tungstens which would otherwise have been unobtainable, and most of the business of this kind that we have secured has been through the use of the four-light, 40-watt tungsten cluster on a flat rate.

While the tungsten lamp will eventually be in universal use, and while the new 40-watt lamp is a great improvement over the ones originally turned out, it would seem to be for the best interests of both the central station and the manufacturers that the change be extended over a reasonable period, instead of concentrated into a few months. Possibly the regular dealers, with slight assistance from the lighting companies, can put out the tungstens as fast as the conditions warrant.

REPORT OF THE MINNEAPOLIS GENERAL ELECTRIC COMPANY, MINNEAPOLIS, MINN.

Tungsten lamps were originally introduced into Minneapolis nearly two years ago. These lamps were of foreign make and were at that time in the very early stages of experimentation. These lamps were tested for wattage and voltage tests and also for light tests. They did not prove very satisfactory, especially in view of their extremely high cost, which made them utterly useless for commercial purposes. About six months later, when the American type of lamp was introduced by the General Electric Company, we again made a series of tests to determine the efficiency and commercial value of this lamp. In this test most encouraging results were obtained. It was, however, not until three or four months later, that, through the medium of the newspapers of this city, and through direct advertising to our customers, did we advise the use of this lamp on the basis of economy to the consumer, sacrificing a temporary reduction in revenue to this company.

These lamps were received with much appreciation by the customers, but gave considerable trouble on account of their weak mechanical construction at first. Time, however, has remedied this defect, and the present great demand by users of electric light, and the amount of new business which it has brought to this company through the reduction in the cost of electric lighting is certainly most encouraging. After slightly over a year of active campaigning we are pleased to advise that we now have installed in Minneapolis approximately 60,000 tungsten lamps. As to the approximate number furnished by this company we are unable to advise, as there are in all some twenty-five or thirty dealers in the city, together with many outside parties, who are selling these lamps.

The sizes which are most generally used in this city are 60- and 100-watt and mostly of the frosted type. We have single installations amounting to as many as 1000 lamps. These are used in large wholesale stores, and at the city schools.

As to the effect to revenue, resulting in the introducing of tungsten lamps in this city, other than a momentary decrease caused by the first installation of these lamps, we feel confident in saying that any central station is justified in highly recommending any form of new high-efficiency lamp which would prove an economizer to the consuming public. Our campaign of introducing these lamps was carried on almost entirely through the medium of local daily papers. We used at times full pages in all three of these papers, showing in graphic forms the comparative value per unit of cost of carbon filament lamps and tungsten filament lamps.

The tungsten lamp has made possible in Minneapolis a very effective municipal street lighting system which has been received with great enthusiasm. This lighting consists of highly ornamental posts, on the top of which is placed one pilot light and four side lights, pilot light enclosed within 16-in. light alabaster globe, side lights enclosed within 12-in. alabaster globes. Further details of this installation we will be pleased to furnish upon request.

For commercial store lighting the best results have been given through a medium of 100-watt tungsten lamps enclosed within diffusers. With tungsten lamps we use Holophane shades almost entirely when the lamps are used in unit form.

Another feature which is of considerable advantage to the central station, particularly in a city which by nature of its development has its business interests throughout a large territory, is the voltage regulation which the tungsten lamp makes possible.

In the life tests made on municipal street lighting we find the average life to be 730 hours. Some, however, still burning, have been in use daily for over 6000 hours.

Each shipment of tungsten lamps received by this company is nearer perfection as far as mechanical construction is concerned, and we do not question the fact that tungsten lamps will before long be handled with as small a filament breakage as the present carbon filament lamp.

We have this spring received a new source of revenue from the installation of urban district ornamental lighting with series tungstens used as illumination. One hundred-watt units used in an upright position are used for this purpose.

REPORT OF NEW ORLEANS RAILWAY AND LIGHT COMPANY, NEW ORLEANS, LA.

It must be borne in mind that the tungsten lamp in its first inception was not very successful in its introduction, but it has gradually increased and been more perfected. It is only within the

last five or six months that they have been introduced into this territory to any extent and the manufacturer of each kind has been pushing them, promising great reduction in consumption and greater brilliancy. In many instances the consumers have made their installations much greater than they had under the old system of the carbon lamps, consequently their bills are running higher than they otherwise would have been, had they confined themselves to a small average of wattage and size of lamps. Many who were in the habit of using 16s and 32s, placed 60 and 100-watt lamps. Of course it made a greater brilliancy, but did not decrease their consumption.

We believe strongly that the tungsten lamp is the lamp of the future. We are encouraging the use of them. We are not as a small station, selling them or exchanging them, because we were exchanging the ordinary 16-c-p. lamps, and had we sold them our consumers would have considered that we were tacitly bound to make the exchange free of cost; consequently, while encouraging their use, we have allowed them to be pushed, but have always advised our consumers to consult with us before changing their installation, so as to get proper advice as to distribution of light and wattage necessary so as to obtain good results.

We have approximately in use in this territory about 3000 lamps and none have been furnished by our company.

The size of lamps most used are the 25, 40 and 60—except as stated before, when consumers take upon themselves to put in larger lamps.

We have not been able to obtain any new business to any considerable extent with tungsten lamps and we have adopted the policy as related above in our handling the proposition.

We find in some instances, where we have made careful examination, the following differences:

In five cases we find that the decrease in consumption reached 40 to 20 per cent., and in eight other cases the average increase was only about 10 to 20, but in four specific cases where they have substituted for two 5-ampere arcs, eight 60 and two 250 watts, the consumption has increased very nearly 50 per cent. Another case, where they have changed their installation from eight 5-ampere arcs and 35 16s to 21 100-watt tungsten and 16 250-watts, they have increased more than 40 per cent. This goes to prove that if a consumer would apply to the central station for information, better results would be obtained than from buying those offered on the market. We have known of some instances of the increase of the lamp renewals from 10 to 25 per cent. over the marked wattage in our testing room.

REPORT OF THE NEW YORK EDISON COMPANY, NEW YORK, N. Y.

The best we can do is to give approximate answers to your questions, which will be taken up seriatim:

1. We estimate that between 200,000 and 300,000 tungsten lamps are now used within the territory of this company—Manhattan Island, the Bronx and Yonkers.

2. We have probably furnished 25 per cent. of all the lamps in use.

3. The sizes most generally used are the 25- and 40-watt lamps. Apparently a majority are of the General Electric type.

4. It would be difficult to give the effect upon the company's revenue. The general effect upon the revenue can be only approximated at best. Realizing that the substitution of tungsten for the former lamps has taken place very largely with the long burning lamp in show cases and interiors, we are of the opinion that the effect will lie somewhere between 5 per cent. and 10 per cent.

5. We doubt that we have secured any large amount of new business through the advent of tungsten lamps. Some has been secured, but the aggregate would represent but a small percentage of our installations.

6. The policy pursued by the company has been to advise each of its customers and the public in general of the existence of the lamp and of its economy in the consumption of current.

REPORT OF THE PHILADELPHIA ELECTRIC COMPANY, PHILADELPHIA, PA.

The electric light consumer is quick to see the merits of a lighting unit that will give him twice the amount of light for the same current consumption, or the same amount of light for one-half the amount of money expended.

With these facts patent, we have been able to present the tungsten lamp to our consumers, backed with stronger features than those enjoyed by any other new lighting unit, which has enabled us to install on our lighting circuits approximately 17,000 tungsten lamps, as of July 1, 1909.

There are good prospects for a much faster increase in the introduction of tungsten lamps as compared the past six months, during which period the increase in the tungsten lamps varied from 15 per cent. to 20 per cent. per month over the previous months' installations.

Furthermore, as an added stimulus for further introduction of the tungsten lamps the prices have been reduced, to central station consumers, as per the following schedule:

Watts	Candle Power	Purchase and Renewal Price
25	20	$0.60
40	32 (Small bulb)	.65
40	32 (Large bulb)	.70
60	48	.80
100	80	1.00
250	200	2.00

NOTE.—This special price for renewals is conditional upon the return to the company of the lamp replaced.

Over 95 per cent. of the tungsten lamps connected to its circuits have been furnished by the Philadelphia Electric Comapny. The company has kept the situation well within its own control, due to the special prices for tungsten lamps to central station consumers.

Thrift plays a predominant part with the Philadelphia merchants, which has undoubtedly influenced the size of the tungsten lamp which is in most general use in Philadelphia. In replacing 50-watt Gem lamps we have found the most popular size to be the 40-watt tungsten lamp—the consumer taking the benefit of more light for less money by this substitution.

With new installations, we find that the 60-watt tungsten lamp is proving quite a favorite and will, in the course of time, become as popular as the 40-watt tungsten lamp.

The small 25-watt tungsten unit is rapidly becoming a favorite for points where good illumination is required for intermittent and occasional use, and where a number of lamps are desirable for lighting effects along certain defined plans of distribution. This is proven by the fact that the 25-watt unit has increased from 12 per cent. to 18 per cent. of the total tungsten installations.

The following table gives the comparative percentages of the various sizes of the tungsten lamps now connected to the circuits:

25 watt	18%
40 watt	38%
60 watt	26%
100 watt	17%
250 watt	1%
	100%

The effect on central station income is as yet problematical. From a study of a number of typical installations it was noted that a variety of conditions were liable to result. In some cases the consumer will pay the same with the tungsten installations as was the case with carbon lamps—the consumer taking advantage of the increased illumination. In other cases the consumer will be satisfied with the same illumination as heretofore, thereby reducing the revenue to the central station company as much as 50 per cent. The indications were that during the early stages of the introduction of the tungsten lamp the revenue to the central station company would be reduced about 12 per cent. where

the tungsten lamp is substituted for the carbon lamp.

In a given number of cases where tungsten lamps have been introduced, 60 per cent. have shown an increase in revenue while 40 per cent. have shown a decrease in revenue. Both the increase and decrease were 17 per cent. more and less than the former revenue; whereas the total revenue of the combined cases showed a decrease of 5 per cent., due to the fact that the greater number of increases occurred with smaller installations. This leads to the conclusion that with the smaller installations we may look for increased revenue, which cuts down the decreases in the larger installations. This, furthermore, proves that the tungsten lamp will popularize the use of electric light with the small consumers.

New business has been secured to a considerable degree, with tungsten lamps, by the extension of electric service with existing consumers and the introduction of electric service with new consumers, displacing gas service.

The data recently compiled when compared with the earlier computations shows that the decrease in the total revenue has dropped from 12 per cent. to 5 per cent., further proving the more liberal use of the tungsten lamps since their adoption.

Taking the total tungsten lamp installations, we find that 21 per cent. of the tungsten installations replaced a number of incandescent or arc lamps giving equal candle power, consequently reducing the income.

Twenty-one per cent. (21 per cent.) of the tungsten lamp installations replaced a number of incandescent or arc lamps using equal watts, hence keeping the income the same—the consumer obtaining more light for the same money.

Thirty-three per cent. (33 per cent.) of the tungsten lamp installations replaced gas, giving the consumer as much or more light than he had before and the electric company securing an increased revenue from the sale of electricity.

Twenty-five per cent. (25 per cent.) of the tungsten lamp installations have been introduced for absolutely new business.

We have found that one of the best methods of introducing tungsten lamps is to make practical demonstrations on a loan proposition for a limited period, placing a lew lamps at desirable locations in the consumer's premises. This brings the favorable qualities of the lamps direct before the consumer and is productive of good results, in most cases leading to an order for the lamps placed on demonstration and an extension of the tungsten in the consumer's installation.

This method of introducing the tungsten lamp is supplemental to general advertising, which is steadily maintained, both through distribution of pamphlets and special articles in the bulletins issued by the company.

To meet certain conditions, we adopted the plan of making a special tungsten fixture and lamp lease, supplying a two or three 100-watt tungsten fixture on a monthly rental and maintenance cost on the following basis:

\$1.25 per month for 2-lamp fixture, of 200 watts
1.75 per month for 3-lamp fixture, of 300 watts

The consumer agreeing to pay for such rental and maintenance charges on the same dates as bills for current to be rendered to the consumer under the regular lighting contract.

We made further proviso that at the end of one year the consumer owned the fixture and the lighting company agreed to renew the lamps and maintain the fixtures thereafter, at the following charges:

50 cents per month for 2-lamp fixture, of 200 watts
75 cents per month for 3-lamp fixture, of 300 watts

This method is meeting with a fair measure of success, particularly in displacing gas installations.

The following is a comparison of a few tungsten lamp installations:

Consumer No. 1. Cloak and Suit Store.

Old installation: 808-8-c-p. carbon, 52-16-c-p. carbon, 97-50-watt Gems, 1-25-watt Gem, 8-5-ampere arcs. Total watts, 35,815.

Date changed to tungsten, July 23, 1908.

New installation: 507-8-c-p., 27-16-c-p., 54-50-watt Gems, 1 arc, 5 amperes, 36-25-watt tungsten, 134-40-watt tungsten, 1-100-watt tungsten. Total watts, 26,120 = 27% Decrease.

	INCOME FROM	
	Old Inst.	New Inst.
July........	\$108.95	\$105.93
August.	64.04	99.87
September. .	136.86	115.85
October.....	182.33	186.54
November...	208.46	252.81
December...	190.26	279.87
January....	293.28	259.23
February....	217.68	277.55
March......	199.22	210.24
April.......	308.88	253.67
May........	256.86	227.70
June........	181.47	213.83
Totals..	\$2,248.29	\$2,483.09 = 10% Increase.

Consumer No. 2. Clothing Store.

Old installation: 18-16-c-p. carbon, 151-8-c-p. carbon, 32 arcs, 5 amperes, 4 h.p. Total watts, 24,414.

Date changed to tungsten, July 1, 1908.

New installation: 59-8-c-p. carbon, 1-32-c.p. carbon, 130-50-watt Gems, 4 h.p., 4-40-watt tungsten, 130-100-watt tungsten. Total watts, 24,514 = .4% Increase.

	INCOME FROM	
	Old Inst.	New Inst.
July........	\$199.58	\$159.41
August.	209.09	167.98
September. .	253.08	197.42
October.....	328.03	294.62
November...	417.38	342.29
December...	453.38	361.44
January.....	430.13	359.86
February....	365.98	361.37
March......	373.10	372.17
April.......	309.60	347.26
May........	309.72	349.34
June........	281.66	293.84
Totals..	\$3,930.73	\$3,607.00 = 8% Decrease

Consumer No. 3. Shoe Store.

Old installation: 19-8-c-p. carbon, 142-16-c-p. carbon, 40-50-watt Gems. Total watts, 9670.

Date changed to tungsten, May 23, 1908.

New installation: 14-8-c-p. carbon, 6-60-watt tungsten, 35-100-watt tungsten. Total watts, 4280 = 56% Decrease.

	INCOME FROM	
	Old Inst.	New Inst.
June........	\$129.06	\$50.08
July........	124.09	51.44
August.	89.97	53.14
September...	104.08	50.69
October.....	135.81	58.43
November...	144.72	64.87
December...	160.79	71.00
January.....	181.84	84.49
February....	166.59	70.38
March......	81.25	65.02
April.......	66.10	69.56
May........	56.70	72.65
Totals..	\$1,441.00	\$761.75 = 47% Decrease

Consumer No. 4. Haberdasher.

Old installation: 16-4-c-p. carbon, 3-8-c-p. carbon, 40-50-watt Gems. Total watts, 2410.

Date changed to tungsten, December 20, 1908.

New installation: 1-50-watt Gem, 36-40-watt tungsten, 15-100-watt tungsten. Total watts, 3530 = 46% Increase.

	INCOME FROM	
	Old Inst.	New Inst.
December...	\$58.07	\$62.25
January.....	46.12	48.53
February....	40.79	42.45
March......	35.43	48.06
April.......	33.48	45.23
May	33.91	34.56
June........	33.48	34.81
Totals..	\$281.28	\$315.89 = 12% Increase

Consumer No. 5. Cigar Store.

Old installation: 6-8-c-p. carbon, 35-16-c-p. carbon. Total watts, 1930.

Date changed to tungsten, October 1, 1908.

New installation: 4-16-c-p. carbon, 20-60-watt tungsten, 6-100-watt tungsten. Total watts, 2000 = 4% Increase.

	INCOME FROM	
	Old Inst.	New Inst.
October.....	\$28.16	\$32.92
November...	32.36	42.97
December...	32.87	39.71
January.....	36.24	43.31
February....	36.62	39.78
March......	33.72	33.21
April.......	29.06	28.64
May........	30.51	24.48
June........	31.52	19.53
Totals..	\$291.06	\$304.55 = 5% Increase

Consumer No. 6. Haberdasher.

Old installation: 62-50-watt Gems, 18-187-watt Gems, 4 arcs, 4½ amperes. Total watts, 8466.

Date changed to tungsten, August 8th—September 15th, 1908.

New installation: 2-32-c-p. carbon, 18-50-watt Gems, 1-40-watt tungsten,

13-60-watt tungsten, 5-100-watt tungsten. Total watts, 2420 = 71% Decrease.

INCOME FROM	Old Inst.	New Inst.
October.....	$25.25	$30.70
November...	31.89	28.01
December...	34.56	31.97
January.....	40.20	40.42
February....	34.56	84.56
March......	34.56	31.20
April.......	34.58	27.65
May........	45.14	27.64
June........	50.24	40.66
Totals..	$330.98	$292.81 = 12% Decrease.

Consumer No. 7. Shoe Store.

Old installation: 62-4-c-p. carbon, 19-8-c-p. carbon, 17-50-watt Gems. Total watts, 2660.

Date changed to tungsten, October 14, 1908.

New installation: 60-4-c-p. carbon, 46-40-watt tungsten, 24-60-watt tungsten. Total watts, 4480 = 68% Increase.

INCOME FROM	Old Inst.	New Inst.
October.....	$21.91	$32.67
November...	21.78	45.96
December...	29.50	46.71
January.....	23.62	38.40
February....	21.60	33.12
March......	19.18	29.26
April.......	18.20	30.38
May........	16.37	25.16
Totals..	$172.16	$281.06 = 63% Increase.

Consumer No. 8. Cigar Store.

Old installation: 8-8-c-p. carbon, Old installation: 62-4-c-p. carbon, Total watts, 1114.

Date changed to tungsten, November 24, 1908.

New installation: 8-8-c-p. carbon, 27-3-c-p. carbon, 11-60-watt tungsten. Total watts, 1224 = 9% Increase.

INCOME FROM	Old Inst.	New Inst.
November...	$15.79	$11.61
December...	18.98	15.91
January.....	14.81	12.90
February....	14.71	11.91
March......	12.87	11.61
April.......	9.77	9.96
May........	9.15	7.20
June........	5.48	7.82
Totals..	$101.56	$88.92 = 12% Decrease

Consumer No. 9. Residence.

Old installation: 4-8-c-p. carbon, 73-16-c-p. carbon, 12-32-c-p. carbon. Total watts, 7509.

Date changed to tungsten, November 7, 1908.

New installation: 4-8-c-p. carbon, 57-16-c-p. carbon, 12-32-c-p. carbon, 16-40-watt tungsten. Total watts, 7349 = 2% Decrease.

INCOME FROM	Old Inst.	New Inst.
November...	$21.42	$24.83
December...	21.97	29.58
January.....	22.58	29.48
February....	25.32	33.10
March......	5.81	29.20
April	23.09	38.11
May........	20.39	35.51
June........	16.70	27.23
Totals..	†157.28	$247.04 = 57% Increase.

Consumer No. 10. Saloon and Hotel.

Old installation: 138-2-c-p. carbon, 59-4-c-p. carbon, 20-8-c-p. carbon, 1-16-c-p. carbon. Total watts, 3491.

Date changed to tungsten, October 5, 1908.

INCOME FROM	Old Inst.	New Inst.
October.....	$42.27	$56.50
November...	46.35	62.50
December...	45.77	62.31
January.....	52.55	61.72
February....	47.36	56.11
March......	46.41	53.13
April.......	40.32	51.73
May........	37.69	49.87
June........	50.68	48.47
Totals..	$409.40	$502.54 = 23% Increase

New installation: 138-2-c-p. carbon, 17-8-c-p. carbon, 16-60-watt tungsten, 6-100-watt tungsten. Total watts, 3726 = 7% Increase.

REPORT OF ROCHESTER RAILWAY AND LIGHT COMPANY, ROCHESTER, N. Y.

Since the tungsten lamp campaign was started by this company, something over a year ago, it has been our endeavor to push the larger units in the business section of the city with a view to increasing the illumination and not decreasing the wattage.

At the present time we have approximately 22,000 lamps on our circuits, of which more than 75 per cent. have been furnished by the company.

Inasmuch as the demand seems to have the preference in favor of the 60-watt units, we have put our best efforts toward pushing the 100-watt lamp with the result that at the present time we have about the same number of each size on our lines. This is entirely due to instructions given our solicitors at the beginning of the campaign to push the large units, which has resulted also in the installation of an exceptionally large percentage of 250-watt lamps, which have been used both on new business as well as in the replacement of arcs and carbon lamps wherever practical, special care being given by our illuminating engineers to make the distribution of light uniform, and in fact to make the 250-watt equipment an ideal lighting installation.

Would state in connection with the above that in very few cases has the consumer changed from this lamp to the smaller units.

We have taken data of the consumption on 15 consumers having a complete installation of tungsten lamps, this being taken for the past year and also for the corresponding months of the previous year covering their old installation. The result we find to be an increase of 8 per cent. on the total year's business, the percentage varying from 3 per cent. to 20 per cent. for different months. In several cases extra lamps have been added within the last two months.

In reference to many of the large consumers, it is impossible to make an accurate comparison, for the reason that all tungsten, arc and carbon lamp consumption is metered together, but the percentage of increase, it is safe to say, is more than the above. We have obtained considerable business with the tungsten lamp that we would not have obtained otherwise.

As this is a combined gas and electric company, we have made no campaign to replace gas arcs. In fact, in very few cases is gas used for lighting in the business section of the city. The business has been increased by the larger volume of light used by individual consumers, due in a large degree to rivalry as to the most artistic effects, in both window display and interior lighting, and this is where the tungsten proposition is strong, and materially increasing the income of the company. Although the percentage is small, with a satisfied consumer, our chances are very good for an increased income due entirely to the introduction of the tungsten lamp.

We are using the most improved Holophane glassware, at the present time installing the satin finish shade, which we find is a great improvement, and with a frosted bulb lamp makes a very artistic equipment.

One of the policies adopted by this company to encourage the use of the tungsten lamp, and at the same time being a strong inducement for the consumer to deal direct with the company, is the maintenance proposition, making four inspections per month, as we are doing, and, in addition to the renewals of blackened and burned-out lamps, keeping the glassware in good condition, washing and cleaning the same when necessary at the exceedingly low price we think is doing more to encourage the use of the tungsten lamp than any one scheme yet adopted.

The prices are as follows:

On 40, 60 and 100 watt lamps, installation of 8 lamps or over, 8 cents per month per lamp.

Less than 8, 10 cents per month per lamp.

250-watt lamps, 10 cents per month per lamp.

From the above prices you will see we have another strong point in favor of the 250-watt lamp: Smaller cost of maintenance for the same volume of light.

Summing up the whole tungsten lamp situation in Rochester, we find it very satisfying from the company's standpoint, and from the consumers' end also.

One of the first complete tungsten installations was in a large clothing house, the same being installed on approval. At the end of the period, the party claiming they were not satisfied, we removed them, putting back their arc installation. After using the arcs for two months, they came to realize their mistake and reordered a complete tungsten equipment. Would state in this connection that this was done without any solicitation on our

part; and since that time the company has sold them two large electric signs; they have outlined their building, and the income from this one consumer has increased over 25 per cent. Although the cost to the company has been considerable in this case, on account of the approval proposition, it is certainly an ideal example of increased revenue through the adoption of the tungsten lamp.

REPORT OF UNION ELECTRIC LIGHT AND POWER COMPANY, ST. LOUIS, MO.

Since we have only handled the tungsten lamp since Jan. 1, 1909, our experience in this connection has been rather limited.

The approximate number of tungstens in service on our line is, as near as we can estimate, from 15,000 to 18,000.

The approximate percentage of such lamps that our company has furnished is about 60 per cent. At the present time we are supplying practically all of the tungsten lamps in this territory, and control the situation, while at the outset the local supply dealers had control.

The size of the lamp most common in use is the 60-watt, for the reason that it is generally used in four-light clusters, replacing electric or gas arcs and Nernst lamps.

From analysis of 30 odd locations, which have modified their installations, substituting tungsten lamps for other and older forms of illuminants, it would appear that there would be a reduction in revenue to the company of about 20 per cent. We feel, however, that the tendency is to use more light, burn the lights for longer periods, and, in general, the additional light is welcomed for approximately the same outlay of money. The change has been so gradual as to be unnoticeable upon the total receipts. The connected load where tungstens have been substituted having fallen off at a greater percentage than the consumption, causes an increase in the kilowatt-hours per kilowatt demand, which, of course, is desirable.

The tungsten lamp has also enabled us to secure certain classes of business, which have been hitherto unobtainable, such as replacing gas, particularly among the smaller merchants. We have found it very useful to recommend tungsten installations in the case of dissatisfied customers whose bills appeared excessive.

Regarding policy, we might explain that we had practically agreed to retail the tungsten lamps to consumers at the same prices at which the supply dealers were selling them. The supply dealers soon took advantage of this situation, informing our patrons that we were handling an inferior and insufficient lamp, and advancing the argument that the company was not actively pushing the introduction, etc., of tungsten lamps, on account of reducing the revenue to the company, and we are daily in receipt of letters from our consumers advising us to call for our arc lamps, Nernst lamps, etc., which had been replaced, and the displaced apparatus thrown to one side. We therefore reduced the price of tungsten lamps to a point at which the supply dealers could not compete, the prices being as follows, with provisions for allowance on renewal:

	Prices at which tungsten lamps were previously sold.		Present reduced prices at which tungsten lamps are now sold by us to our customers.		Prices at which burned-out tungsten lamps, purchased from us (when returned with unbroken bulbs) may be exchanged for new lamps, by those whose contracts entitle them to free lamp renewals.	
Watts.	Clear.	Frosted.	Clear.	Frosted.	Clear.	Frosted.
25	$ .85	$ .90	$ .65	$ .70	$ .50	$ .55
40	1.00	1.05	.75	.80	.60	.65
60	1.40	1.50	1.00	1.10	.85	.95
100	1.75	1.85	1.30	1.40	1.00	1.10
250	3.50	3.65	2.50	2.60	2.00	2.10

We are also advertising the tungsten lamp in four-light cluster rather extensively, permitting the consumer to pay for the fixtures by installments of small monthly payments with the light bill.

REPORT OF PACIFIC GAS AND ELECTRIC COMPANY, SAN FRANCISCO, CAL.

The following remarks will cover our conditions in San Francisco for the San Francisco Gas and Electric Company, in Oakland for the Oakland Gas Light and Heat Company, and in Sacramento for the Sacramento Electric Gas and Railway Company.

Sacramento can be quickly disposed of for the reason that this has always been what might be termed a flat-rate town. In view of the Eastern practice, this may be somewhat of a surprise to you, for Sacramento is one of the first cities to be supplied extensively by water power, and the original promoters of hydro-electric supply at this point seemed imbued with the idea that when once a plant was built that there were no expenses, and that it was better to have a flat rate and save the cost of meters.

We have, of course, learned differently in the meantime; but owing to the extent of the flat-rate system, we have not yet seen our way clear to do away with the flat rates entirely. There was also very keen competition in Sacramento between the different water-power companies, so that the rates are very low. For some time past, wherever possible, we have been endeavoring to get consumers to use meters, and the tungsten lamp has been one of the factors to aid us in so doing; in other words, the original flat rates were made upon the basis of the carbon filament lamp, and some time ago we made a rule that no more flat rates would be given where any device was used other than the standard carbon filament lamp. That was done, as it will readily be seen, that, with a reasonably low meter rate, it would be cheaper for the consumer to place tungsten lamps on a meter basis than to continue to use the carbon filament lamps on a flat-rate basis.

For this reason we cannot aid in obtaining a general idea of the actual savings in the use of tungsten lamps, for the reason that where tungsten lamps have been installed we have changed from a flat rate to a meter.

The introduction of tungsten lamps in Sacramento has just commenced, and we would estimate that we have 1200 installed, practically all of which have been sold through the local dealers, as the Sacramento Company does not in itself supply any lamps. The bulk of the lamps that have been used have been used in saloons, stores, etc., and have been of the 100-watt size. The effect upon our revenue in Sacramento, as stated above, we cannot of course give you, but we have a direct effect in that by replacing the carbon filament lamps with tungsten lamps we have obtained consumers who are much more satisfied than heretofore. We have not set any particular policy in Sacramento as yet regarding the tungsten lamps other than that of requiring the consumer to change to a meter basis. We of course recommend their use, as we feel that the light is certainly much more satisfactory than with the old lights.

In San Francisco the conditions existing are extremely peculiar, and it is absolutely impossible to give any statement which would be of any value as a comparison. The fire of 1906 destroyed all of our large consumers in the way of stores, etc., etc., and these consumers, immediately following the fire, moved into temporary quarters outside of the business district, and in these temporary quarters installed carbon filament lamps, as this was the only means available at the time. Expecting to move again into their permanent quarters, none of our customers felt like making any change from the carbon filament lamp to the tungsten lamp until the move was made. Practically all have now moved into their down-town quarters; but as the size of the store is different

and the number of lamps vastly different, there can be no comparison in the matter as between the present bills and any past bills which they have made with the carbon filament lamps.

The situation is still further complicated by the advent of opposition companies, which has tended to lower the rates and to still further change conditions. The tungsten lamp in San Francisco is becoming very popular, and we believe that we now have installed upon our circuits about 200,000 of these lamps. Of these the company has not sold over 5 per cent. The lamp in most general use for business purposes is the 40-watt lamp. This seems to be the nearest to the old 16 c-p. standard, and we think this was the principal reason why it was adopted. We have, however, a number of installations using the 250-watt tungsten lamp with the corresponding Holophane reflector. These are used largely in the place of arc lamps and the Nernst lamps. There has been also a very noticeable demand for the 25-watt lamps, and at the present time the low voltage, small candle-power sign lamp is just coming into vogue. As explained above, the effect upon our revenue we cannot give.

In the matter of effect on obtaining new business with the tungsten lamps, which we did not get formerly, we beg to state that this company also controls the gas output, so that competition as between the two is not as it would be were the companies independent; but we feel sure that the tungsten lamp will, in a short time, if the price can be reduced, be the best possible competitor in the electric light companies' hands as against the Welsbach burner. We have, as far as the policy goes, been encouraging the use of the tungsten lamp to the extent that we are supplying our consumers with tungsten lamps in unbroken packages at practically cost, both because we believe in the introduction of the lamp, and because we are able to obtain a lower price for the lamps that any of our competing companies. We are receiving a discount of 20, 10, 10 and 5, plus the freight, from the General Electric Company, and are reselling these lamps at a discount of 20, 10 and 5, the other 10 per cent. just about paying for the handling and delivering.

In so far as the Oakland Gas Light and Heat Company is concerned, we would state that tungsten lamps are only used in the business districts, for the reason that all of the residence lighting is at 200 volts, and we are only just beginning to receive 200-volt tungsten lamps.

In the matter of policy this is the same as in San Francisco, as is also the type of lamp used. As to the effect of tungsten lamps, we are enclosing herewith a little table showing the watts and candle-power installation this year and last year, and the revenue received this year and last year over the same period. We have no examples in which the tungsten lamps have absolutely displaced the carbon filament lamps, the majority of the installations being more in the nature of additional installations.

Analyzing the table, it is interesting to note that averaging the whole installation, the watts per candle-power installed last year were 3.4, whereas this year the average has been reduced to 2.73; the revenue last year per candle-power per month was 1.8c., whereas this year the revenue per candle-power was 1.48c.

REPORT OF ST. PAUL GAS LIGHT COMPANY, ST. PAUL, MINN.

The approximate number of tungsten lamps now in service in St. Paul is about 3000, all of which have been furnished through dealers in this city or agents of the lamp companies, as this company has not kept stocks of these lamps at any time.

The size of the lamp in most general use is the lamp rated at 40 watts. The 40-watt lamp seems to be the most popular size, since it combines the saving in cost of current and cost of lamp better than any other size for most locations. The 60-watt lamp means increased cost of current, while the 25-watt increases the cost of the lamp in proportion to the resulting lighting.

The result of the use of tungsten lamps on revenue appears to be generally: (1) A tendency to decrease both the connected load and the revenue. (2) It gradually increases revenue up to or exceeding the original amount with a decrease in the original connected load.

We have used tungsten lamps in displacing gasoline lighting and in obtaining other business either difficult or impossible to secure.

The responsible dealers here have pushed the use of tungsten lamps on a permanent basis, using the argument of more light for the same money, and this has almost invariably resulted in securing satisfied consumers and increased business.

The sale of tungsten lamps in this territory has been left entirely to the dealers, and in such locations as we would deem advisable the consumer is advised to purchase lamps from the dealer. We are not, however, conducting an active campaign for tungsten lamps, except as above stated, in competition with gasoline plants or for special situations.

NAME	ADDRESS IN OAKLAND, CAL.	LOAD OF				COMPARISON OF REVENUE			
		1909		1908		1909		1908	
		WATTS	CANDLE POWER	WATTS	CANDLE POWER	K.W. HOURS	REVENUE	K.W. HOURS	REVENUE
LAVENSON & RENWICK.	459 13th ST.	13989	4864	16000	4640	1152	65.51	1234	70.12
SMITH BROS.	462 13th ST.	7385	3048	13760	4000	509	31.95	536	41.42
MATT KERR	421 14th ST.	3299	1281	11000	3200	873	59.84	967	61.47
BARKER & CO.	26 SAN PABLO	1155	476	1540	450	120	10.60	160	14.00
PIERCE H'D'W. CO.	1108 B'D'W'Y.	6910	2912	11300	3280	1234	70.45	1796	84.87
CALIF. OPTICAL CO.	1113 B'D'W'Y.	6650	2240	3860	1120	219	18.09	357	26.61
FORUM CAFÉ	1156 B'D'W'Y.	25492	8814	21600	6280	4550	159.25	5080	203.20
E LENHARDT	1159 B'D'W'Y.	7855	5316	6210	1810	3384	135.16	2377	100.97
SELBY BROS.	1057 WASH.	5270	1985	4840	1410	955	40.60	809	58.18
BACON B'L'D'G.	11th & WASH.	71000	23420	74129	22100	4360	174.40	4520	180.80
MESMER SMITH	1126 WASH.	13400	4378	8920	2600	1620	81.00	1490	76.07
A. SCHLEUTER	1156 WASH.	2130	1700	11560	3370	641	50.58	1250	69.86
TOTALS		164,535	60,434	184,719	54260	19617	897.43	20576	987.57
-		WATTS PER C.P. $\frac{\text{TOTAL WATTS}}{\text{TOTAL C.P.}}$ = 2.73		WATTS PER C.P. $\frac{\text{TOTAL WATTS}}{\text{TOTAL C.P.}}$ = 3.4		1.48¢ PER C.P. PER MO. (RATED C.P.)		1.8¢ PER C.P. PER MO. (RATED C.P.)	

COMPARISON OF LOAD AND REVENUE WHEN USING CARBON FILAMENT AND TUNGSTEN LAMPS FOR JUNE 1908 AND JUNE 1909 RESPECTIVELY.
PACIFIC GAS AND ELECTRIC COMPANY, SAN FRANCISCO, CAL.

REPORT OF THE WASHINGTON WATER POWER COMPANY, SPOKANE, WASH.

Approximate number of tungsten lamps now in service:

	25 W.	40 W.	60 W.	100 W.	250 W.	Total
Sold on Company Account	3,387	5,391	690	312	..	9,780
Electrical Contractors' Sales	1,425	2,800	1,200	216	48	5,689
Grand Total	4,812	8,191	1,890	528	48	15,469
Percentage of lamps sold by us	70%	66%	37%	60%	..	63%
Percentage of lamps sold by others	30%	34%	63%	40%	..	37%

It will be noted that both the dealers and ourselves have sold more 40-watt lamps than any other. We attribute this to the made-up tungsten fixtures which call for from five to nine lamps and are usually 40-watt lamps, taking the place of the direct-current arc. We also note that show-window lighting can be secured with a 40-watt lamp as against former 50-watt carbon filament lamps.

You will observe, from the comparatively small number of lamps we have out, that it could not seriously affect our revenues. We submit, however, herewith, some comparisons showing the increases and decreases as compared with incandescent and arc lighting.

Concerning the obtaining of new business with the tungsten lamp, will state that we probably had as many Gem and meridian lamps in use per capita as any central station in the country, which we renewed free of charge, and have absorbed about all of the business obtainable, such as the displacing of gas. In commercial lighting we have no other competition, so that we cannot say that we have not been able to reach all classes of trade and really monopolized the same before the tungsten lamp came in.

We have no special policy to encourage the use of the tungsten lamp, further than to advise with our consumers in the displacing of carbon filament or Gem and meridians in show windows and the displacing of arc lights. For general lighting, we get about two-thirds in wattage in displacing arc and incandescent lights with tungsten, and for window lighting we will average better than three-quarters in capacity on the original installation.

To size up the situation generally, with very few exceptions we have found our bills have very nearly, if not quite, maintained themselves, notwithstanding the reduction in capacity and that the superior quality of the light has led tungsten consumers at once to light their stores longer hours than they otherwise would; in fact, they are willing, in most cases, to pay as much for light, or even more, when including the cost of renewals.

We find that the consumer is ready to take from the dealer his first installation, and that the dealer is willing he should do so, even though he sells it slightly below cost, for the accommodation of his customer, and the consumer is too apt to think the original installation of lamps is the best.

We sell lamps in original packages at cost, tested lamps over the counter at about 25 per cent. advance, and do not believe that we will be able to control the lamp situation as formerly until we sell the lamps at something below what it is possible for the dealer to provide them at.

REPORT OF POTOMAC ELECTRIC POWER COMPANY OF WASHINGTON, D. C., WASHINGTON, D. C.

In compliance with your request for information regarding the tungsten lamp situation in Washington, we beg to submit for your consideration the following statement, which particularly covers the points mentioned in your communication:

We now have approximately 18,000 tungsten lamps in service in this city, of which about 95 per cent. have been furnished by this company.

The lamp in most general use is the 100-watt size. This is due to the longer life, greater illuminating capacity and the fact that less investment in wiring, fixtures and lamps is required.

Out of a selected list of about 30 customers who have changed from other electric lamps to the tungsten, we find a slight increase in revenue of a little more than 1 per cent. This comparison covers a period of about six months; we think that it is a rather favorable one. We believe it is due to the policy of this company to advocate *more light* and not *smaller bills*.

The tungsten lamp has been of considerable assistance to this company in securing new business which was previously unobtainable. Quite a number of small stores, the proprietors of which in the past would not consider electric light, owing to the increased cost over gas, are now illuminated by tungsten lamps.

The special policy and plans of this company might be stated as follows: A representative of the General Electric Company has, for several months, been working in this territory with satisfactory results. In most cases the representative in charge of the territory, or one of his assistants, solicits the business, and the General Electric Company's representative assists as much as possible. In many cases where it seems impossible to convince the prospect by ordinary argument, a fixture, or possibly several lamps, with proper shades and holders, is installed. We find that this demonstration of the lamps is of considerable help in securing difficult prospects.

Altogether, our experience with the tungsten lamp has been very satisfactory. There have been some instances where the lamps have been found to be defective, but we have always been liberal in such cases, it being our experience that where the customer is properly started he soon comes to understand the nature of the lamp, and afterward needs no more attention than other patrons.

COMPARATIVE BILLS, SHOWING CONSUMERS WHO HAD ARC AND INCANDESCENT INSTALLATIONS, JANUARY, 1908, AND CHANGED TO TUNGSTEN INSTALLATIONS IN JANUARY, 1909.

	Arc and Incandescent, 1908	Tungsten, 1909
Murgittroyds, Drugs	$85.50	$83.85
Cohn Brothers, Furniture	68.00	58.00
Dreyfoos, Clothing	54.80	75.50
Hurd Clothing Co., Clothing	77.75	77.05
Groff, Tailor	24.20	33.50
Woodmansee, Cigars	33.00	24.60
L. H. Bonsall, Clothing	27.20	29.50
German Bakery	72.75	50.00
Ritter Drug Co	79.85	80.95
Central Cafe	59.60	49.60
Berry's, Department	349.95	332.50
Blakely Dry Goods Co., Department	99.70	117.20
Hendershott & Baird, Saloon	9.50	8.65
Swanson Brothers, Saloon	44.15	38.55
Percentage of loss ($26.50) 2.4%	$1,085.95	$1,059.45

COMPARATIVE BILLS, SHOWING CONSUMERS WHO HAD ARC AND INCANDESCENT INSTALLATIONS IN JUNE, 1908, AND CHANGED TO TUNGSTEN INSTALLATIONS IN JUNE, 1909.

	Arc and Incandescent, 1908	Tungsten, 1909
McLean & Fowler, Restaurant	$31.35	$34.05
McLaughlin & Anderson, Restaurant	9.25	13.30
Gimble & Taylor, Saloon	20.00	10.30
Le Claire Shoe Co., Shoes	3.35	1.05
Jodoin & Davies, Dry Goods	55.00	40.00
Bonsall Clothing Co., Gry Doods	15.75	13.50
A. W. Dahlstrom, Saloon	22.00	18.05
T. E. Westlake, Grocery	20.00	20.65
A. E. Cowles, Saloon	27.50	24.45
Caputa & Lanza, Cigars	25.00	8.15
Max Erman, Clothing	19.45	7.60
J. W. Oakes, Restaurant	94.00	64.50
M. J. Kalez, Restaurant	113.50	107.70
A. M. Murray, Restaurant	32.00	8.80
Loomis-Waite Co., Clothing	17.30	20.80
M . & S. Schulcin, Shoes	20.00	20.00
J. E. Brady, Saloon	15.50	14.75
Percentage of loss ($113.30) 21%	$540.95	$427.65

The Advantages to Electric Companies of Central Station Steam Heating

By CHARLES R. BISHOP

Member of the A. S. H. & V. E.—A. S. M. E.—A. I. E. E.

The subject of central station heating is one, I presume, which has come in some form or other to the attention of every manager of an electric plant in New England, yet possibly there are but few members of this branch of the National Electric Light Association who have any comprehensive idea of the great advancement of the enterprise during recent years, or know of the large number of companies that have undertaken the supply of steam for commercial heating purposes, and still fewer who know from actual experience what can be accomplished in this field. That such a condition exists in New England seems at first thought strange, in view of the fact that other forms of public utility service have been developed to the highest degree in this section. It is due, possibly, to the extensive development of gas, water, electric lighting and street railway enterprises which have required such constant and unremitting attention from the management that sufficient time could not be spared for a thoughtful consideration of central station heating.*

While New England has been justly recognized as standing foremost in the development of public utility enterprises, it has also in a measure enjoyed the distinction of being almost ultra-conservative, and has no doubt been waiting for the full development of district steam heating before seriously taking up this field of service.

During the past 30 years the number of cities supplied with central station heating have increased rapidly year by year; large quantities of data, both reliable and useful, have been compiled; methods of construction have been standardized; correct conditions of operation fully ascertained; proper construction and insulating materials necessary to secure low maintenance cost and small transmission loss have been developed; equitable methods of charges for service rendered have been introduced through the development of accurate meters in which the public place confidence—therefore, it would seem that the time was at hand for the public service companies in New England to exploit this field as thoroughly and as successfully as they have the others.

Before taking up the present state of district steam heating, it may be well to touch a little upon the history of the enterprise.

At the time of its conception, in the year 1876, there was no practical knowledge of anything pertaining either to construction or operation, maintenance of underground lines, the quantity of heat required in various classes of building, cost of generating and delivering steam, or any data upon which to base the charges for services rendered. A number of years passed before sufficient data had been collected to determine what had been the causes of excessive transmission losses, large repair bills, and generating costs so high that profitable and satisfactory operation was difficult. Notwithstanding the fact that the early results had been unsatisfactory, it appeared to those most directly interested that there remained enough of an encouraging nature to justify further effort. Experiments were continued upon a much larger scale and many different kinds of insulating materials were thoroughly tested, together with several methods of providing for expansion and contraction—each class of experiment requiring considerable periods of time to determine real value. In this way the enterprise progressed along lines of improvement in construction and insulation, but with little attention being paid to economy in generating steam, to methods of selling or to general management.

In 1880, and during the early period of development, a system of steam mains was installed in Lynn, consisting of long lines of pipe of small diameter, designed to carry relatively high pressures, very imperfectly insulated and with practically no protection against the effects of water which more or less surrounded the mains. The construction of the plant was carried through without appreciation of engineering requirements, no provision made for relieving the mains of condensation except through entrainment; boiler-house economies were not considered, and the management was entrusted to men without experience and wholly incapable. The result is obvious.

About the same time a plant was installed in Springfield, Mass., under practically the same methods of construction as were used at Lynn, but, with better management, succeeded in supplying service for over 20 years. Shortly afterward, a very extensive system of hot water distribution was installed in Boston, but was doomed to failure in a short period of time. As there was but little detailed information published regarding the hot-water plant at Boston, the impression became quite general that the plant had been a steam-heating system, which was incorrect.

Other failures of steam-heating plants occurred, however, in various parts of the country, but totaled less than a dozen, with causes of failure due to the same sources in all instances, namely: poor construction and insulation of the underground system, management left to the inexperienced men, a lack of proper means and methods of charging for steam consumed, and a deficiency in data of all kinds. Contrast the few failures with the great number of successes which total more than two hundred cities, a small proportion indeed, and a much less percentage of failure than has occurred in electric lighting or street railway service, particularly the horse and cable lines.

In the New England States there are 172 cities having a population of over 5000, and still in but three of them is there a district-heating system of any magnitude, while Pennsylvania, having 82 cities of over 5000 inhabitants, can claim central station heating plants in at least 69 cities. Illinois has 51 cities of 5000 population and over, out of which 30 have more or less extensive systems of heat distribution, and in addition, there are heating plants in eight cities in Illinois of less than five thousand population.

The question that now suggests itself is: Why are so few New England cities supplied with this service? Is it on account of climatic conditions? No; because steam-heating is a success as far south as Birmingham, Ala., where snow is almost unheard of and the mean winter temperature is higher than the mean temperature of October alone in New England. Is it on account of the heating season not being of sufficient length? Certainly not. Is it on account of a lesser difference between the cost of fuel to the central station company and to the consumer? No; statistics are proof of that. Is it

*Paper read before the New England Branch of the National Electric Light Association's Summer Meeting held at the Wentworth Hotel, Newcastle (Portsmouth), N. H., September 9th–10th, 1909.

on account of local conditions? It cannot be said that that is the reason—in fact, there is not a reason, but on the contrary every reason is decidedly in favor of district steam heating in New England as compared with any other section of the country.

The heating season here is regarded as of more than average length and severity. The cities are more compactly built, particularly the residence portions. The cost of fuel for central station use as compared with that purchased by the individual user is in favor of district heating. The class of business available is better, and the prosperity of the community is acknowledged to be greater than in other sections.

As the methods of construction of steam distribution plants is one now recognized to have become standardized, and descriptions have been given from time to time in the various publications to which most of the membership of this Association are subscribers, or for those who may not have read such articles, information can be procured from manufacturers and contractors, it would be of greater interest at this time to touch upon that phase of the enterprise designated as "Results of Operation," under which there are two principal subdivisions, namely, those comprising the operation of plants which supply no public utility service other than steam for heating and known as "live steam plants," and those which supply steam for heating, but utilizing the exhaust steam resulting from the operation of their electric plants and universally referred to as "exhaust steam plants."

Since this Association is composed of representatives of electric light and power companies, let us devote ourselves to a consideration of the "Commercial Possibilities of Operating an Exhaust Steam Heating Plant in Connection with the Operation of Present Stations," a topic suggested by a member of your executive committee.

Is there a market and demand for a central station supply of steam for heating purposes? I think you all will agree that there is, and no doubt many of you have been approached by owners of business blocks or residences to furnish a supply of heat, and others have been disappointed that their solicitors of contracts for lighting and power have not succeeded in procuring a considerable amount of additional business which would readily have been secured had you been able to supply steam for heating as well as electricity for light and power.

Is there as good a market for steam heat as there is for electric light and power? I believe there is a better market—in a sense electric light can be regarded as a luxury, so also can a

PLANT No. 1.

K. W. H.	Coal, Lbs.	Water, all purposes, Lbs.	Coal, Cost.	Water, Cost.
1,902,970	16,383,649	145,302,510	$21,091.82	$692.77

Oil and Waste.	Boiler Room Labor.	Engine Room Labor.	Total.	Steam Receipts.	Ave. Net Rate.
$596.36	$2,473.37	$2,008.88	$26,863.20	$37,190.35	40c.

Steam investment outside of station, including street mains, services, trenching, repaving, street traps and meters, $122,070.16.
Space heated—approximately 10,000,000 cu. ft.
Oct. 1, 1908—May 25, 1909.
Combination plant—operated three seasons—City of 17,500 population.

PLANT No. 2.

K. W. H.	Coal, Lbs.	Water, all purposes, Lbs.	Coal, Cost.	Water, Cost.
541,767	6,768,661	48,131,094	$7,974.55	$463.20

Oil and Waste.	Boiler Room Labor.	Engine Room Labor.	Total.	Steam Receipts.	Ave. Net Rate.
......	$1,029.00	......	$9,466.75	$12,497.85	40c.

Steam Investment—approximately $48,500.00.
Oct. 1, 1907—May 1, 1908.
Combination plant operated five seasons. City of 10,000 population.

PLANT No. 3.

K. W. H.	Coal, Lbs.	Water, all purposes, Lbs.	Coal, Cost.	Water, Cost.
1,087,233	12,316,000	75,556,071	$22,333.55	......

Oil and Waste.	Boiler Room Labor.	Engine Room Labor.	Total.	Steam Receipts.	Ave. Net Rate.
......	......	......	......	$29,020.94	50c.

Electric receipts for same period $41,112.42
Steam investment approximately $45,000.00
Eight heating months of 1908. Space heated approximately 7,900,000 cu. ft.
Combination plant operated eight years. City of 10,000 population.

PLANT No. 4.

K. W. H.	Coal, Lbs.	Water, all purposes, Lbs.	Coal, Cost.	Water, Cost.
2,498,508	24,837,136	177,053,950	$15,523.21	$1,072.39

Oil and Waste.	Boiler Room Labor.	Engine Room Labor.	Total.	Steam Receipts.	Ave. Net Rate.
$370.48	$4,432.97	$2,378.86	$23,777.90	$25,931.68	27c.

Steam investment—approximately $103,000.00
Oct. 1, 1908—June 1, 1909.
NOTE.—Steam rate should be at least 60% higher.
Space heated about 16,000,000 cu. ft. City of 43,000 population.

PLANT No. 1.

BOILER AND ENGINE ROOM COSTS.

8191 tons bituminous coal @ $2.57½ per ton	$21,091.82	
Wages, firemen and helpers	2,473.37	
Wages, engineers	2,008.88	
Water	692.77	
Miscellaneous Supplies	596.36	
		$26,863.20
Add to the above 10% for interest, depreciation, etc., on steam investment		12,207.01
		$39,070.21
Receipts from sale of steam		37,190.45
		$1,879.76
Totalized switchboard cost per K. W., including interest and depreciation on steam investment, $1,879.76 divided by 1,902,970 =		.000987c.

PLANT No. 2.

3334 tons 661 lbs. coal costing	$7,974.55	
Boiler room wages for 7 months	1,029.00	
Engine room wages (not given) assumed for 7 months	980.00	
Water	463.20	
Oil and waste	100.00	
		$10,546.75
Interest and depreciation at 10% on steam investment, approximately $47,650.00		4,765.00
		$15,311.75
Heating receipts		12,497.85
		$2,813.90
Totalized switchboard cost per K. W., $2,813.90 divided by 541,767 =		.00519c.

NOTE.—As their heat customers are heating for only about two-thirds of the previous cost to them when generating with their own apparatus, this company's rate should be 50% higher with a corresponding increase in revenue.

PLANT No. 3.

7,224 tons, 399 lbs. coal, including water	$22,904.05	
Wages in boiler room	2,305.45	
Wages in engine room	1,271.65	
Oil and waste	568.01	
		$27,049.16
Add to the above 10% for interest and depreciation on investment of approximately $45,000 in steam mains		4,500.00
		$31,549.16
Heating receipts		35,053.45
Surplus		$3,504.29
Note that after paying all generating charges, also interest and depreciation on investment in steam mains, there remained a totalized switchboard surplus per kw. hr. of $3,504.29 divided by 1,081,150 =	0.324c.	

PLANT No. 4.

12,413 tons, 1136 lbs. coal, costing	$15,523.21	
Wages in boiler room and hauling coal and ashes	4,432.97	
Wages in engine room, including oilers	2,378.86	
Water	1,072.39	
Oil and waste	370.48	
		$23,777.91
Add to the above 10% for interest and depreciation on investment of $103,000.00 in steam mains, etc.		10,300.00
		$34,077.91
Heating receipts		25,931.68
		$8,146.23
Totalized switchboard cost per K. W., including interest and depreciation on steam investment, $8,146.23 divided by 2,498.508 =		.00326c.

NOTE.—These results being obtained while selling steam for practically fifty per cent, of what should be charged and compete with cost of fuel to individual users in that city.

public distribution of water, of gas, or of street railway service. To no one of us is a public service of any of the above-mentioned commodities necessary. In this locality we can live without artificial light; if we arise with the sun and work until it sets we would labor more hours than the average man now works; we need not have our residences or places of business supplied by a water company, since we can live without such service, taking our supplies from waterways, wells or cisterns; in place of riding on street cars we could live down-town, walk, ride a bicycle or drive a horse. Heat is recognized as an absolute necessity for the maintenance of human life; it cannot be secured in this latitude from nature's sources during winter; it cannot be successfully stored for long periods of time; it must in some manner be manufactured for immediate consumption, and, therefore, to a greater degree is demanded of public service companies than are the other named commodities.

Can your company supply heat at a cost comparable with that at which an individual himself can produce it? It is a fact that many of you are manufacturing heat in the form of steam, but what becomes of it? Simply converting into mechanical energy in the form of electricity from 8 to 14 per cent. and throwing the balance away, either into the atmosphere or into condensers? The plant operating non-condensing may have 8 per cent. heat efficiency, and the condensing plant a possible 14 per cent. conversion. Why not sell this large amount of otherwise lost energy for a price which will pay the original total fuel cost, including also such other expenses as water, oil, waste and labor in boiler and engine room? Can it be done? Yes. Others are not only doing that very thing, but are also earning interest and depreciation on the cost of the steam distributing system. In this connection let me cite the results of a few companies.

Let us now consider the results secured by companies operating plants which supply no public utility other than steam heat.

This company pays regularly a six per cent. annual dividend, and has created in addition a surplus of approximately $60,000.00, which surplus is equal to 50 per cent. of capital stock (no bonds issued).

SEASON 1908–09

Fuel Lbs.	Water Consumption all purposes. Lbs.	Total Operating Cost Fuel, Water, B. H. Labor, including Salaries, Taxes, Repairs, etc.	Income from Sale of Steam @ 40c. per M.
32,644,166	261,216,438	$34,598.72	$57,004.68

Fuel Lbs.	Water Consumption. Lbs.	Cost Coal Hauling, Removing Ashes, etc.	Cost Firing, Water, Boiler House Labor, Salaries, Taxes, and Sundries.	Income from Sale of Steam.
40,337,248	302,917,521	$27,529.51	$19,346.50	$72,071.10

Cubic feet of space heated, 22,811,900.

Net earnings for past season approximately 14 per cent., which is about the average result of this plant.

Cubic feet of space heated, 15,939,907.

Plant investment, including real estate, $176,618.67.

Capital stock issued, $177,000. (No bonds.)

This company pays six per cent. dividends annually and has an undivided and uninvested surplus account of $30,865.84, after having charged off three per cent. annually for depreciation.

All repairs and renewals are charged into operating account.

You will note by a comparison of these two live steam plants that the latter company manufactured over 57 per cent. more steam per cubic foot of space heated than the first-named company, and this difference is almost wholly accountable by the fact that one company charges for steam furnished upon the basis of consumption as shown by meter records, while the other company operates entirely under the flat rate method. Applying the revenue per 1000 cu. ft. of space of the latter company to the space heated by the former, the gross revenue of the first named would then be approximately $103,110.00, or nearly 81 per cent. greater than the present income.

Recently, the president of that company was asked why they did not charge at least a 60-cent rate, which would not increase the cost of heating beyond a point where the consumers could save money by operating their own plants, and his answer was: "Should we make such an increase in rates, either a new heating company would immediately be formed, and with a more modern and efficient plant compel us to reconstruct under to-day's standardized and improved methods of construction and insulation in order to compete with them, or force us out of business. As a second condition, our consumers would probably appeal to State authorities for an examination of our water."

To ascertain if such increase in rates was due to a lack of sufficient profit under present rates, and such an examination would show that in all probability we are earning a greater profit than the companies in this city now profitably operating such plants as electric light, street railway, gas or electricity.

I have chosen the two plants referred to because they are operated in cities of approximately the same size, in the same State, under the same climatic conditions, and occupy the same class of territory.

I think you will all agree that the results given prove that exhaust steam heating can be profitable in any city, and that plants furnishing no service other than steam heat are also profitable.

Influencing the degree of success of district steam-heating plants there are several conditions, viz.:

First—The climatic conditions should be such as to insure a good market for the sale of steam.

Second—The generating station should be reasonably adjacent to the districts which it is proposed to serve, simply in order to reduce the investment necessary to reach the business.

Third—The local conditions under which steam is sold for heating should be such as will permit fixing a rate which, while well within economic limits from the standpoint of the consumer, can still be sufficiently high to pay a satisfactory profit on the investment over and above the cost of manufacturing steam, including depreciation and amortization.

Fourth—Efficient management.

Fifth—The meter system of charging. (Measured service.)

Sixth—The total amount of business secured to the total amount procurable.

Seventh, but by no means the least—The installation of the plant under standardized methods of construction which have proven efficient through years of actual operating experience, and by reason of which the transmission losses are reduced to a minimum, and depreciation low.

An eighth condition should be included for "live steam plants" operated purely as such, viz:

In any city where a central heating plant is constructed, a sufficient territory must be reached by the underground system to insure a volume of business in which the profit existing between generating cost and selling price does not exceed fixed burden. Where the heat is supplied by exhaust steam a sufficient volume of business should be secured to at least utilize, during minimum demand heating, the full amount of exhaust steam from any single engine unit. Station piping should be so arranged that any engine can be operated, condensing, non-condensing, or under back-pressure while furnishing steam for heating, without reference to the manner of operating any other engine in the

station. This can be accomplished without much additional cost for piping, but is very often neglected, resulting in back-pressure being carried on a portion of the engine plant without compensating advantages. To secure maximum results the demand for steam for heating should be slightly in excess of the maximum amount of exhaust steam available at all times.

Considerable care should be taken in the design of a proposed underground system of steam mains, and in order to properly determine its cost, gross and net earning power, the average and peak demands, and the probable effects upon present operating conditions, the method of procedure is generally as follows:

A careful examination is made of all the territory, both business and residence, within a distance of from one to one and three-quarter miles from the generating station, depending upon local conditions. Manifestly unfavorable districts are then eliminated; a scaled map is made of the balance of the territory, upon which is shown the location and cubic feet of space of each of the buildings contained therein. Upon this map there should also be noted the type of building construction (wood, brick or stone); classification indicated (retail or wholesale business, manufacturing, public building, hotel, boarding-house, apartment house, theater, residence, etc.). Information is also secured from local records, or from the nearest source, covering the maximum, minimum and mean monthly outdoor temperatures, average monthly wind velocity and average monthly relative humidity. Then with this information collected and using compiled data covering average and peak monthly heat demands in the various classes of buildings to which service has been rendered in other cities having similar climatic conditions, the average, peak and total steam demands in each block can be determined and noted on the map. In this manner the steam demand is calculated for each block from the extreme point of delivery back to the station, resulting in a fairly accurate estimate of quantity of steam that will be required for the heating season, each month and at peak demands. The size of mains from the station and in the various blocks is determined by using tables of carrying capacities of modernly constructed and properly insulated underground steam mains, operated under a maximum initial pressure of five pounds above atmosphere, and transmission drops of one-quarter pound per 1000 lin. ft. of main. As much or as little of the ultimate completed system may then be installed as is deemed desirable for the first year's construction, and these mains will be of proper size to meet the inevitable growth of the plant, without eventually resulting in serious overloading with its attendant excessive back-pressure or impaired service.

When available, monthly station records of coal and water consumed in the manufacture of electricity are plotted graphically, the monthly demand for steam is likewise plotted, hourly and monthly electrical output considered, and thus the extra amount of fuel and water required is found. With the known cost of fuel, water, etc., it becomes a simple matter to calculate what will be the increased operating expense. The curve of steam demand at the generating plant is made up of consumers demand, transmission losses and unaccounted for steam.

The next step is to establish a rate at which the steam is to be sold, and this depends strictly upon local conditions. As a general rule the average rate per 1000 lb. steam sold is approximately 10 per cent. of the cost to an individual user of a ton of anthracite coal, if that is the kind of fuel generally used. As an example, where anthracite coal is sold to the consumer at $7.00 per ton, the central-station company should receive an average of 70 cents per 1000 lb. of steam, which rate would be slightly in favor of the consumer on a basis of actual British thermal unit efficiency. Cumulative sliding scale rates are usually adopted in order that automatically the larger consumer should pay a lower average price per 1000 lb. of steam than the smaller consumer, the justness and reason of which is apparent.

The investment is made up of cost of power plant connections, street distributing mains, service mains, trenching and paving, consumers and street meters and street traps. With these costs known, together with the cost of generating and operating, amount of transmission loss (which is a fixed quantity dependent upon the number of square feet of surface of underground mains), and probable income from the different buildings, the profit which will accrue when serving 25%, 40%, 50%, 75% or 90% of total available business in the whole territory or any portion of it, may be estimated within a reasonable degree of accuracy.

It is not necessary, nor would it usually be advisable, to cover the full amount of territory in the first year's installation, but a sufficient amount should be covered to insure profitable operation.

Another very important factor must also be considered, namely, the additional amount of electrical business that can be secured through your ability to furnish, not only electric light and power, but heat, with the additional profit resulting from such increased electrical sales. A feature of possible greater importance is the fact that with an extensive heating plant operated in connection with electric light and power, you are practically insured against a competing plant being installed even though the threatened competition may be of hydro-electric nature. I make this statement understandingly. Illustrative of this feature, I will cite the following instance:

In a certain city there existed a company furnishing all the gas and electricity used with the exception of the street railway load. It had a station equipped with boilers, engines and generators to be used in emergency times; it had its own hydro-electric plant but of somewhat limited capacity, and it also had a contract with a near-by hydro-electric company covering a long term of years, which agreed to furnish any amount of current up to a maximum of 30,000 h.p., at a price close to ¼ cent per kilowatt-hour, monthly bills being based upon the average of the highest, daily, one-minute peaks occurring during the month, but with no "firm h.p." restrictions. The company sold current at rates which averaged less than a cent per kilowatt-hour.

In the same city there was a company operating an extensive system of district steam heating, which company installed a thoroughly modern steam electric generating plant, consisting of well-designed single-cylinder four-valve engines, alternating current generators, etc. Within six months they secured a majority of the commercial lighting business, practically all of the residence electric lighting load and a fair amount of the smaller and higher-priced power business. This was accomplished without any cutting of rates, but due in a large measure to better and more uniform service, which is always true of a steam-driven electric plant as compared with a hydro-electric plant with its usual long and extensive high voltage distribution lines. Details of subsequent events are extremely interesting, but to mention would increase the length of this paper beyond the allotted time, so I will only give the outcome.

The competing companies were consolidated into a third company with the company first in the electrical field in control of the stock of the consolidated company. An interesting fact now appears. In view of the favorable contract held by the company for the purchase of all the cur-

rent ever likely to be needed, and with electric demand far in excess of the ability of the steam-generating plant ever to serve and not exhaust to the atmosphere, what method of operation would be adopted? Would the plant be kept for stand-by purposes, shut down as an electric plant, or continued in operation? Without changing any of the conditions the consolidated company continued for six months the operation of the steam electric plant to determine, for themselves, the manufacturing costs under the combination of generating current and selling exhaust steam. The results were such that they then bought and installed additional steam engines and generators which more than doubled the former capacity, and have since, during heating seasons, operated the generators not only to their full capacity but with heavy overloads during peak demand hours. Even throughout the night hours electricity is manufactured, although current could be supplied from the outside hydro-electric company at no cost to the local or purchasing company—due to the already-mentioned fact that the company purchases current on the one-minute peak basis, and the peak had already occurred, thereby fixing the bill for the 24 hr. service, this condition existing on account of the desire to increase the amount of exhaust steam.

More complete details and additional records of results in other cities can be given to companies desiring same.

It may be of interest to learn how transmission losses may be determined. At low points in the system of underground steam mains, at intervals of from 500 to 1000 ft., depending upon local conditions, street traps are placed in manholes and the condensation discharged through meters. Service connections are always taken from the extreme top of the steam mains so that practically all of the condensation of steam occurring in the distributing system reaches the traps and is measured by the street meters. This loss in modern system does not exceed the transformer core losses of most electric plants. It may be stated that the percentage of transmission losses and unaccounted-for steam is considerably less than the percentage of transmission, transformer and unaccounted for losses of electrical distribution.

While it must be recognized that the construction cost of a steam distributing system greatly exceeds the construction cost of an electrical distribution system, still it is a well-known fact that the average consumer pays many times more for heat than he does for light. The number of hours of steam service is fully 30 per cent. greater than the total number of lighting hours of the year, and steam heating has the added advantage of being continuous during the 24 hr. of each day throughout the heating season.

The rates for steam service supplied by an electric company should be based on the assumption that all steam sold will be manufactured expressly for heating service, and then there would be no question of there being a profit for all steam furnished in excess of the exhaust steam utilized. Upon this basis no company need have any fear of contracting for additional heating business, being limited only by the capacity of the generating plant.

In conclusion, let me call special attention to a few important facts brought out in the foregoing:

Experimental period has passed—present development equal to that of other public utilities.

Underground construction standardized.

Meters developed to a high degree of accuracy.

Live steam heating is profitable.

Exhaust steam heating is more profitable.

Supplying heat from your present electric stations will—

Increase—value of present investment.

Increase—number boiler horse-power hours and its attendant increased boiler efficiency.

Increase—number engine and generator horse-power hours resulting in increased electrical efficiency.

Increase—wonderfully the number of heat units actually utilized of the total number manufactured.

Increase—load and power factors.

Increase—kilowatt output.

Increase—income from electric sales.

Increase—income from plant operation.

Improve—position of company to keep out a competing company.

Improve—position of company to keep out isolated plants.

Increase—net earnings.

Increase—dividends.

Prepayment Meters

By F. G. VAUGHEN

The prepayment device in various forms is commonly used in vending wares of many kinds. It has been used with success in marketing small wares, at a small expense, and a good profit.*

The electric prepayment device is, therefore, not new in principle, but as it has only been used occasionally, it can not be discussed from the standpoint of general use.

The application of the prepay method to sale of electricity is more recent and much more less general than with gas. The prepayment gas meter was developed abroad a quarter of a century ago and has since become prominent in this country and abroad.

There is no underlying reason why the prepayment electric meter should not become as popular, and play quite as important a rôle in the vending of electricity as does the prepayment gas meter in the vending of gas.

Nearly all manufacturers of electric meters, both in this country and abroad, have developed some form of prepayment device, varying from a form where the dropping of the coin does the work of operating the device, to those having an extremely complicated mechanism.

I have understood that the adoption of the prepayment electric meter has been far more general in Europe than in this country, and has met with success — particularly with supply companies of municipal ownership. While our experience has been more or less limited, I feel that it has been such that there is no diversity of opinion as to the numerous advantages of a reliable prepayment electric meter, and that it would be of material assistance in sale of electricity.

Now, let us consider where such a device could be used, and where the additional investment (to cover the prepayment device) would be outweighed by pay in advance, economy, increased consumption, greater satisfaction, etc. All companies selling electricity number among their customers some to whom:

Frequent visits of a collector is necessary;

Frequent sending of bills, labelled "please remit";

Frequent explanations have to be made as to the correctness of the bill;

Threats to cut off the supply unless bill is paid;

Cut off of supply is necessary;

After cut off of supply, bill is paid, and then necessary to reconnect the service;

*Association of Edison Illuminating Company 1909.

The monthly bill is bothersome and the payment at a specified time becomes a hardship.

Then there is the customer who is here to-day and gone to-morrow, with perhaps an unpaid bill. Such customers are in all communities having a floating population, such as large cities, summer resorts, manufacturing towns, college towns, etc. The apartment house furnishes what can be called the transient customer.

Again, there is the small consumer where the monthly bill is so small that the work involved in reading the meter, keeping the account, sending out bills, etc., all of which is usually done by different departments, greatly reduces the profit derived from such customers.

All customers which are mentioned, and perhaps others familiar to the supply companies, are revenue producers, but not in the average—profitable, due to expense involved for reasons outlined above. Yet the supply companies can not afford to lose or refuse to do business with them. The deposit is a medium through which the supply companies protect themselves with many such consumers, and it is justified in cases where the credit standing is uncertain, yet the prospective customer objects to the demand for a deposit before the service is connected, and in many instances will do without electric light rather than make the required deposit. This opens up the question—if there is not a large amount of business to be had, and which the supply companies are not enjoying, if it were not for the uncertainty of the money returns for electricity supplied.

The prepayment electric meter provides the simplest and most feasible solution of cases herein cited. How simple it would be for the commercial department of the supply company, with the electric prepayment meter at its disposal, to deal with prospective customers, either through solicitation or application, that have no credit standing and whose business looks desirable, except for the one reason—poor or doubtful pay, to eliminate the usual routine, and say, "We will put you on prepayment basis," and, therefore, close the business without delay and further expense to the supply company.

The prepayment electric meter has an extensive field, and that its adoption has not been more general is doubtless due to the fact that of all the many devices, invented and manufactured, comparatively few have proven reliable for an indefinite period.

To meet its field, it is evident that the successful prepayment electric meter should be of simple and robust construction, made from good materials, and with the best of workmanship, having as few delicate parts as possible.

It is the tendency of the designer of to-day to follow as near as possible, mechanical principles, thereby aiming to avoid a complicated mechanism.

The fact should not be lost sight of, however, that no automatic device—no matter how simple—can be left to itself year in and year out with no attention whatsoever, and be expected to do its work in an entirely satisfactory manner. Occasional and perhaps ultimate complete failure under such circumstances is inevitable. Doubtless they should receive more attention than the ordinary type of meter, for the mechanism of the simplest is more complicated than the ordinary meter, and correspondingly, more likely to become deranged.

The care and adjustment should not be delegated to an inexperienced person, who has no interest in the device other than to see the "wheels go round." The responsibility for the upkeep should rest upon some man, or men, who are adepts in the fine mechanical devices, and have preferably had some experience in actual manufacture or repair of clocks, or other automatic mechanisms. Such men are not hard to find and the results obtained will far more than compensate for the increased expenditure.

The fundamental requirement of any meter is accuracy, both initial and continued, and it applies with equal—if not greater—force to the prepayment meter as to the ordinary type. The prepayment meter must not only record accurately the energy consumption, but the exact ratio between the coins deposited and the dial indication must always be maintained.

If the prepayment meter records too fast or too slow, it is less likely to be discovered as promptly as with the ordinary meter, where one month's consumption is compared to another. The customer does not keep a record of the frequency, nor the dates when deposits are required, and unless the company reads the dial regularly and compares with previous readings, there is strong possibility of error going undetected.

If the number of coins deposited is less than should be according to dial reading, rise is at once given to the suspicion that the customer is beating the meter; or, conversely, if the dial reading is less than it should be for the money deposited, the company is suspected of actually charging a higher rate than contracted for, and a disgruntled customer must be appeased.

The prepayment meter must be infallible. Each time a coin is deposited the customer must be properly credited and the time of the opening of the switch extended correspondingly. If the coin is deposited simultaneously with the operation of the tripping device, the two must act independently so that the net result is the same as if the coin had been deposited either before or after the tripping device had operated. In other words, the device should be capable of crediting and debiting at the same time. Upon using up the last coin's worth of energy, the switch must not fail to open and break the circuit, nor fail to close immediately upon the insertion of another coin.

"For ways that are dark and tricks that are vain, the Heathen Chinee is peculiar." This is as true of many consumers of electricity as of the "Heathen Chinee," and attempting to beat the meter—particularly a prepayment meter—is their especial delight.

It is doubtless impossible to design an automatic device that at some time, by some person, can not be tampered with and beaten, but they can and should be so made that evidence of such work remains and the culprit can be apprehended with quite as effective results as if he is actually convicted of dishonesty.

Every prepayment meter should be so made that a coin of larger dimension than that for which it is designed shall not enter the slot, and a smaller coin pass through the mechanism without operating it. If a coin or "slug" is attached to a string, the operation of the mechanism should cut the string or render it impossible to pull back the coin. Any device which could be operated by a wire cannot be tolerated.

There is no way to prevent the operation of a prepayment device by counterfeit coins or "slugs," but if used, the supply company will have evidence against the consumer, and claim full value of the legitimate coin.

The coin box should be made as nearly theft-proof as possible. One good method of fastening the receptacle is with a strong padlock of good design, which can be purchased in quantities, at reasonable prices. Another is with a seal. Hence, the coin box should be adapted for both methods of fastening.

Theft on the part of the employee of the company must also be guarded against, and the meter so made that access to the meter itself for purposes of testing can be had without opening and interfering with the coin receptacle. Conversely, it should be possible to open the coin receptacle without opening the meter casing, for the collector is usually unfamiliar with the setting and regulating of the meter, and might inadvertently injure the adjustment.

Hudson-Fulton Celebration

The three-hundredth anniversary of the discovery of the Hudson River by Henry Hudson joined with the centennial of Fulton's inauspicious beginning of steam navigation, furnished the occasion for the most elaborate electric illumination New York has ever seen. The celebration began September 25th with a great parade of harbor craft and pleasure boats, led by replicas of the *Half Moon* and *Clermont,* up and down the North River; about fifty-odd war vessels anchored from 50th Street to Spuyten Duyvil.

ILLUMINATION ON 125TH STREET.

Much of the Jersey side of the river was outlined by incandescent lamps, and the public structures along the Manhattan side were illuminated in honor of the men to whom New York owes so much. All of the war boats were outlined by incandescent lights hanging from the hulls and main rigging.

In the city proper very many of the high bulidings were lighted up to the topmost stories, and not a few were ruggedly outlined in light. All of the East River bridges were silhoutted in incandescents and more than 10,000 lamps were required for each bridge, current being jointly furnished by the New York and Brooklyn Edison Companies.

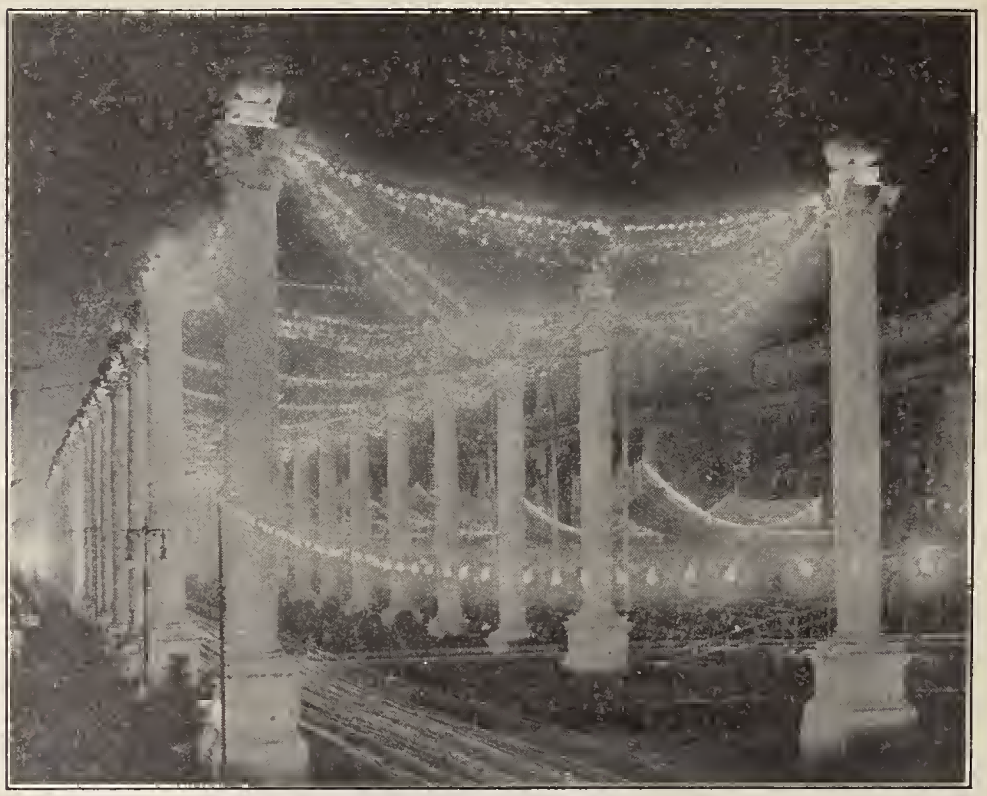
The various important public structures in Greater New York were illuminated by 8-c-p. incandescents spaced in outline suited to the edifice. These included Washington Arch, the Viaduct Bridge on Riverside Drive, Soldiers' and Sailors' Monument, Grant's Tomb and City Hall, as well as the various borough and town halls.

The line of the parade from 110th Street and Eighth Avenue to 59th Street across to Fifth Avenue and down to Fourth Street was illumined by a double string of incandescents, about six miles long. The lamps were carried over either street curb on 25-ft. iron poles and hung about 2 ft. apart. On Fifth Avenue, between 40th and 42th Streets, the Court of Honor was formed by 36 massive white Corinthian columns, each surmounted by a huge golden ball. From their tops, at a height of about 60 ft., there twined incandescents and evergreen in large and beautiful strings from pillar to pillar along the avenue and then across the street from pillar to pillar, and again diagonally from each to the other, making a grand electric canopy of such surpassing beauty that words may not describe it.

THE RYAN SCINTILLATOR IN ACTION.

The Ryan scintillator that was lately used at Niagara Falls was placed at Riverside Drive and 155th Street, a point where it was visible from Jersey, the North River and most of the west side of Manhattan. Forty hugh searchlights of varying color shot enormous beams high in the air, now radiating in fan-like effect and changing from intensest white to the softer greens and yellows; now again shifting bodily from east to west and back again with frightful speed, only to disappear; and then to reappear in another quarter of the heavens, all the time playing in fantastic and fairy fashion on high clouds of steam rising from a 200-h.p. boiler situated some distance in front of the scintillator.

During the entire celebration all of the lighting effects were maintained from dark until midnight.



THE COURT OF HONOR.

High Voltage Tungsten System in Residential Lighting

FREDERICK WELLES PIERCE

Hartford Electric Light Co., Hartford, Conn.

On the introduction of the tungsten filament incandescent lamp, at first sight it seemed the goal of incandescent electric illumination. It was an efficient lamp for the central station to operate and an economical one for the customer to burn. From the manufacturing engineer's and the customer's standpoint the lamp was perfectly satisfactory, giving roughly twice the candle-power for one-fifth less current, and lasting 1300 hr. instead of 700. Where the old 50-watt metallized filament lamp gave 20 c-p. and burned 450 hr. to 80 per cent. of its initial candle-power, the tungsten 40-watt gave 35 c-p. and burned 1300 hr. to 90 per cent. of initial candle-power.*

However, from the central station manager's standpoint of commercial utility, the tungsten lamp was not so pleasing. He had to re-adjust his ideas from a 2½-watt per candle mettalized filament lamp to a 1¼ watt per candle tungsten lamp. How was he to handle the new lamp—on a meter or flat rate? Would he give it away or sell it? And the high cost of the lamp made renewals also a serious problem. Was he to allow the residential consumer with 300 c-p. installed in his house to cut his meter bills in half with no corresponding economy in the cost of maintaining the meter? The lamp was expensive to give away, and the ordinary handling through central station supply departments and the consumers' hands was difficult because it was so very fragile. Breakage losses became very large, and yet every central station manager saw that here was a lamp that would enable him to compete with gas, if he could properly take advantage of its high efficiency, and yet in some way compensate for its high cost and extreme fragility.

With meters costing $4.50 per year to maintain, and as Mr. Insull in the national convention at Atlantic City said, now doing only 40 per cent. of the work formerly done with the carbon lamp, and thus the liability of residential lighting bills being halved by the introduction of the tungsten lamp, the central station manager was forced to some solution of the residential lighting problem, and the only satisfactory one seems to be the introduction of the low voltage tungsten lamp.

The imperfections inherent in the carbon lamp have made house lighting undesirable for electric-light stations which are able to secure any other business, and consequently in the larger cities very few houses are furnished with electric light by any companies that can escape doing so. The carbon lamp has these unavoidable faults: After the first 100 hr. rise it drops rapidly in candle power, and after 400 hr. it blackens so perceptibly as to greatly reduce its light, and no station has been able to remedy these difficulties. The average 16-c-p. carbon lamp burning its natural life of 700 hr. is about 11 c-p., so the consumer gets only two-thirds of what he is entitled to.

The tungsten low-voltage lamp has a slow, gradual increase in candle-power, does not blacken so perceptibly and by a slight sacrifice in efficiency can be made to have a life of almost 2000 hr. Thus the tungsten filament lamp overcomes the principal faults of the carbon lamp, and in low voltages can be made in 10 and even lower candle-powers. One of the chief troubles with the metallized filament lamp was the inability of the manufacturing companies to make a satisfactory 10-c-p. lamp, which is principally in demand in residential lighting. Thus it can be fairly stated that the introduction of the low voltage tungsten makes residential house-lighting a practical and profitable proposition.

The 30-volt or 60-volt tungsten allows of ordinary handling with almost no breakage where there was 19 per cent. loss due to breakage in the 120-

*N. E. Section, N. E. L. A., 1909.

volt 40-watt tungsten. Also where no satisfactory 10-c-p. was manufactured in the high voltage, an excellent 10 and even 4-c-p. is made in the low voltage. The price of the low-voltage lamp is lower than the high-voltage, and it may be almost called a by-product, as its filament may be made from the short cuttings of the high-voltage filaments. Where the 120-volt tungsten requires a special large bulb to accommodate its four filament loops, the low-voltage filament is mounted in an ordinary 10 or 16-c-p. bulb. This makes it particularly convenient in displacing existing lamps in special residential fixtures, ornamental lighting, etc. Also the short filament of the low-voltage lamp makes it practical to burn it successfully at any angle.

The low-voltage system is adapted to present central station supply systems by the use of an economy or balance coil with 112-volt primaries and four 28-volt secondary circuits. Extra taps are brought out on the primary side that admit of exact voltage adjustment on the secondary circuits.

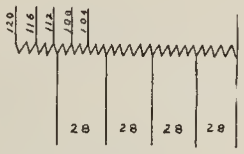


Fig. 1.—WIRING DIAGRAM OF ECONOMY COIL WITH ADJUSTABLE PRIMARY TAPS.

This type of coil can be used equally well with 30-volt or 60-volt tungsten lamps. Referring to the diagram, secondary wires Nos. 2, 3 and 4 give a standard three-wire system, and any two adjacent wires give a standard two-wire system. For 60 volts Nos. 1, 3 and 5 give the three-wire system, and Nos. 1 and 3 or 3 and 5 give the two-wire system.

The first difficulty was found in large houses owing to the drop in long distribution circuits at 30 volts. Under the low-voltage system a lamp of the same candle-power as the old carbon took half again as much current at one-quarter the voltage so that the drop per candle-power installed was about six times that formerly. This could be partially overcome by using the proper primary taps before mentioned. But another difficulty was encountered. When the coil was installed on a residence it rendered useless all the common flat irons, curling irons, fans, sewing-machine motors, etc., and circuits controlling this apparatus had to be re-wired so as to remain on 112 volts, which was expensive, inconvenient and oftentimes almost prohibitive. However, both the drop problem and this last difficulty were partially solved by adopting a 60-volt lamp instead of a 30-volt. This cut the drop to only one-third more than what it used to be instead of six times. Most of the commercial cooking and heating apparatus can be satisfactorily manufactured for 60 volts. The 60-volt lamp seems no more fragile than the 30-volt was, so that breakage is negligible. Its bulb is our standard 16-c-p. bulb. These low-voltage lamps are made in the same standard efficiency as the high-voltage lamps, *i.e.*, 1.1 w.p.c., 1.25 w.p.c. and 1.33 w.p.c.

In the installation of a large number of economy coils of the original pattern with only a two-wire 112-volt primary, difficulty was experienced in maintaining a balance on transformers and the three-wire serial street system. However, there is now manufactured an economy coil with a three-wire 120/240-volt primary, and a three-wire 60/120-volt secondary. This coil simply reduces the whole house voltage suitably for the 60-volt lamp and retains the original balance on both the street wiring and interior house wiring.

Having solved the engineering difficulties in the way of the low-voltage tungsten lamp, the next step was its commercial introduction. An investigation of the records of The Hartford Electric Light Company with 120,000 incandescent lamps on meters installed on its line showed a net income of $1.10 per year per lamp installed. This gave a good basis for the handling of the low-voltage tungsten on a flat rate, and the following proposition is made to the public:

Current for 10-c-p. low-voltage lamp, .10 per month per lamp. Current for 20-c-p. low-voltage lamp, .15 per month per lamp. Current for 30-c-p. low-voltage lamp, .25 per month per lamp.

The first installation of lamps to be furnished the consumer at .20 each for all sizes. Renewals, all sizes, at .10 each. The installation of the economy coil, etc., is done free of charge.

Soon after the advent of the high-voltage tungsten and its introduction in residences on a flat rate basis trouble appeared from the customers purchasing 40-watt lamps and screwing them in in place of the 25-watt lamps without the knowledge of the company, and this fact necessitated the adoption and use of some sort of a maximum demand controller. Such a device is now manufactured that is practical and reliable for commercial use. When a lamp in excess of the number contracted for is turned on, these controllers cause all the lamps to flicker until such excess load is turned off. Sensitive thumbscrew and spring adjustments make the instrument flicker on an excess load of only 12 watts. With the installation of the low-voltage tungsten, the same chance of fraud in exchanging 20-c-p. for 10-c-p. lamps existed, so a maximum demand controller is installed ahead of the economy coil properly adjusted for the load contracted for. A very convenient and cheap combination is used of a three-wire maximum demand controller and the before-mentioned three-wire economy coil as shown in the accompanying diagram.

In connection with the introduction of the low-voltage tungsten lamp for residential lighting, The Hartford

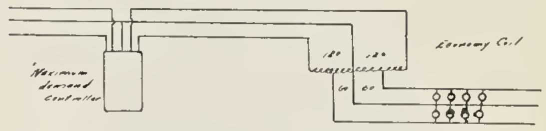


Fig. 2.—ECONOMY COIL IN THREE-WIRE CIRCUIT.

Electric Light Company's commercial department is carrying on an active campaign in the wiring of unwired houses now using gas, etc. We have the following proposition which seems to be extremely popular with the public. A contract job price is made of $35.00, for which the prospective customer's house is properly wired on the three-wire system and six outlets provided, and for these outlets are furnished one 3-light fixtures, two 2-light fixtures, one single-light fixture, one bracket and one drop cord, or a total of 10 sockets or lights. Then the before-mentioned flat-rate prices on the 10, 20 and 30-c-p. low-voltage lamps are quoted and the deal is closed. Thus for $35.00 initial cost and $1.00 per month, a man may have his house wired and burn 10 10-c-p. lamps, etc. If the prospective customer demands a meter, his house is wired for the same price and metallized filament lamps and a meter installed. In case 10 lights are not sufficient, extra outlets will be installed with the original contract at $3.50 each, and extra fixtures at the actual selling price. Most of the contracts run in excess of the 10-light proposition, the average price paid us being $51.00 for an average of 12 10-c-p. and 3 20-c-p. lights at an average income per house of $1.65 per month.

The General Electric Company reports very gratifying sales of tantalum lamps. The sales of this lamp are more than double what they were a year ago, and the lamp appears to be sharing with the demand for high efficiency lamps created by the introduction of tungsten lamps. The tantalum lamp, as at present supplied, is giving most excellent life service.

Denver Electric Railway Convention

At the Denver convention of the American Street & Interurban Association, Oct. 4th to Oct. 8th, electric railway appliances were exhibited by the following firms:

Allis-Chalmers Co., Milwaukee, Wis.—Air-brakes for electric cars, railway motors and controllers. Represented by Frank G. Bolles, J. H. Waterman, J. R. Jeffrey, James Gardner, I. L. Dimm, R. B. McConney, E. W. Stull, F. W. Fanger, George Biaz.

American Steel & Wire Co., Chicago.—Wires and cables for electrical purposes; rail bonds and bonding tools; railway fence. Represented by C. R. Sturdevant, B. H. Ryder, F. A. Keyes, J. M. Holloway, J. D. Sutherland, E. R. Pool, W. H. Williams, W. R. Abbott, E. E. Aldous.

Babcock & Wilcox Co., New York.—B. & W. model of horizontal boiler, and two types of boiler heads. Represented by Charles Onderdonk, William Turner, F. A. Einfeldt, Harry Byer.

Carnegie Steel Co., Pittsburgh, Pa.—One pair wheels mounted on axles showing 89,368 miles of service without turning; piece of track with standard 100-lb. rail with steel crossties showing type of concrete construction; Duquesne rail joints; steel sheet piling for coffer dams; specimen of steel piling used for core walls for dams; skeleton mine, showing mine timber construction with steel shapes and portable steel tie track; soft welding and threading steels; specimens showing hot and cold bends; section of interurban car truck made entirely with Carnegie welding and threading steel; slack barrel hoops for spike and bolt kegs and miscellaneous packages; steel wheels for street and interurban service. Represented by K. E. Porter, C. B. Friday, N. D. Trist, W. E. Berry, J. C. Holding, L. P. Lincoln, R. B. Carr, E. S. Mills, N. M. Hench, E. M. Sparhawk, A. H. Hawkins, O. M. Ash.

General Electric Co., Schenectady, N. Y.—Type M control equipment; complete emergency straight-air brake equipment for motor car and trail car; New York variable release motor car air-brake equipment; railway motors; aluminum cell lightning arresters; Magnetite arc headlights; indicating and recording steam meters; air compressors; A. C. railway signal system; complete line of rail bonds and line material. Represented by F. H. Gale, J. G. Barry, H. N. Ransom, W. G. Carey, C. E. Barry, E. D. Priest, F. E. Case, A. H. Armstrong, S. W. Trawick, W. J. Clark, C. B. Keyes, T. Beran, H. G. Grier, R. E. Moore, H. L. Monroe, J. W. Buell, G. D. Rosenthal, C. C. Pierce, H. M. Winter, A. W. Arlin, A. V. Thompson, C. W. Blivin, H. G. Marsh, W. J. Hanley, Irving Hale, G. A. Woolley, H. C. Glaze.

Johns-Manville Co., W. H., New York.—Porcelain insulators; transite asbestos wood; low-voltage overhead line material; catenary line material; molded insulations; indurated fiber forms for third-rail protection; high-voltage oil-switch tanks and fiber conduit; Noark enclosed fuse and service boxes; fuses and devices for high and low voltage service; J-M guy anchors and mine supplies; friction tape and rubber compounds; asbestos and magnesia pipe and boiler coverings; packings; linolite; desk and table lamps. Represented by J. W. Perry, G. A. Saylor, A. H. Pierick.

Kerite Insulated Wire & Cable Co., New York.—Insulated wires and cables for A.C. and D.C. feeders; transmission; signals; telephone, telegraph, car wiring and house wiring. Represented by R. D. Brixey, Azel Ames, P. W. Miller, J. A. Renton, J. V. Watson, R. E. Eutrick.

McConway & Torley Co., Pittsburgh, Pa.—Janney radial equipment for interurban cars. Represented by Stephen C. Mason, E. M. Grove, I. H. Milliken.

Rail Joint Co., New York.—Continuous, Weber and Wolhaupter rail joints for T, high T and girder rails, both standard and compromise. Represented by F. C. Webb, W. T. McCaskey, W. E. Clark, E. A. Condit, E. L. Vandresar, P. D. Watson.

Roebling's Sons Co., John A., Trenton, N. J.—Reception room. Represented by A. B. Conover, W. H. Slingluff, J. McG. King.

Speer Carbon Company.—A new line of street railway motor brushes made by a new process to conform with the specifications of the engineering association of the American Street & Interurban Railway. This brush was shown for the first time at the convention and was spoken of highly by the engineers.

This brush is made by a new process which makes the brush perfectly homogeneous, uniform, without any laminations and made in four degrees of hardness: Grade H, Grade H-1, Grade H-3 and Grade H-8—for different conditions, and gives a much greater mileage and keeping the commutator in good polish and a chocolate color with no perceptable wear to commutator.

For the past year the company has been running some very elaborate service tests on a number of the largest city and interurban railway systems. The company has completed a sufficient number of tests to satisfy themselves that this new brush meets with all the requirements of the engineers' association.

It is said that the general opinion of engineers was that the better grade brush would be adopted by more than 75 per cent. of the electric railways before the next convention, as they are now giving the matter of proper commutation considerable thought.

Standard Paint Co., The, New York.—Reception room for explaining and recommending P. & B. and S. P. C. varnishes, compounds and insulating tape; also Novac compound for impregnating coils without the aid of a vacuum. Represented by C. E. Smith, B. C. Beckman, John H. Thomas, J. I. Pfeiffer.

Standard Varnish Works, Chicago and New York.—Insulating specialties. Represented by L. Robinson, H. P. Salmon and Denver representatives.

Sterling Varnish Co., Pittsburgh, Pa.—Insulating materials and metal protective paints. Represented by A. S. King, W. F. Hebard, W. V. Whitfield.

Western Electric Co., New York and Chicago.—Railway telephones; portable telephone sets; bells; buzzers; batteries; Electrose insulation; strain insulators; Ideal cap and cone hangers; line and overhead construction material; armature and field coils; Kalamazoo trolley wheels, harps and sand-boxes. Represented by F. D. Killion, R. H. Harper, W. E. Harkness, M. H. Nichols, C. L. Howk, A. Brown, H. C. Biglin, H. Olsen.

Westinghouse Companies, Pittsburgh, Pa.—See item regarding this exhibit under Supply Trade News.

The Westinghouse exhibit at the street railway convention occupied a space of approximately 2500 sq. ft. The companies represented by their displays were the Westinghouse Electric & Manufacturing Co., the Westinghouse Traction Brake Co., the Westinghouse Machine Co., and the R. D. Nuttall Co. These companies represent a capital of approximately $100,000,000, employ about 30,000 operators and their annual output of product amounts to about $70,000,000. The exhibit of the Electric company consisted of railway motors, a complete exhibit of material showing the control of cars and trains by electrical machinery and a line of motors for machine tools. The Machine company showed a complete electric train-lighting plant, consisting of a 40-h.p. generator and a steam turbine; also two LeBlanc condensors and other auxiliary apparatus. The Traction Brake company showed a complete set of machinery for stopping one car, two cars, three cars, or a

train of electric cars, by the air-brake system; also auxiliary apparatus. The Electric company also exhibited, outside of the auditorium, a single-phase car, which will later be in operation on the Denver & Interurban. Besides the 25 members of the office force of the Denver district of the Westinghouse companies, of which L. M. Cargo is manager, the companies were represented by men from Pittsburgh, Boston, Baltimore, Philadelphia, Cincinnati, Chicago, Kansas City, St. Louis, San Francisco, Los Angeles and Columbus, Ohio.

Theodore Inslee Jones

Mr. Theodore Inslee Jones has recently been appointed manager of the sales department of the Edison Electric Illuminating Co., of Brooklyn. In this position he has full charge of the selling end of the company's business, including all contracts for electric light, heat and sign work, together with the supervision of the company's advertising.

Mr. Jones is an electrical engineer, graduated from the Massachusetts Institute of Technology in 1896. In this year he began work in the New York office of the American Telephone and Telegraph Co., being identified with the inspection and traffic departments. Under Assistant General Superintendent Brooks he originated and equipped the first school of instruction for telephone traffic. This has since become an important adjunct of all telephone companies' work. After four years with the American Telephone and Telegraph Co., he took charge of the traffic department of the N. Y. & N. J. Tel. Co., in New Jersey. While this work was arduous it did not prevent him from delivering a course of lectures on telephone and electric light topics before the New York Board of Education. Mr. Jones has continued his lecture work up until the present time.

In the early part of 1907 Mr. Jones accepted a position as illuminating engineer with the Nernst Lamp Co., in New York, and while in this position was offered the managership of the sales department of the United Electric Light & Power Co., New York. His work has been such a signal success that he was invited to take charge—after two years' work with the United Co.—of the commercial end of the Brooklyn Edison Co.

Through the agency of Mr. Jones' force, the United Company, has in the past two years written contracts with over 11,316 new customers, involving an installation of over 500,000 16-c-p. equivalents. During this time the United Company, through one of the larger construction companies of the city, has also introduced alternating-current hoists throughout Manhattan Island and a number of private plants have been shut down for the installation of control station service.

Sewing-Machine Motors

A very interesting application of the General Electric small motors is to the driving of sewing machines. Cuts 1 and 2 show a motor of this type driving a sewing-machine by means of the new General Electric sewing-machine attachment. The design of this device is extremely simple, and it can be attached to any machine of the usual construction in a few minutes.

Either alternating or direct-current motors can be furnished for the operation of sewing-machines.

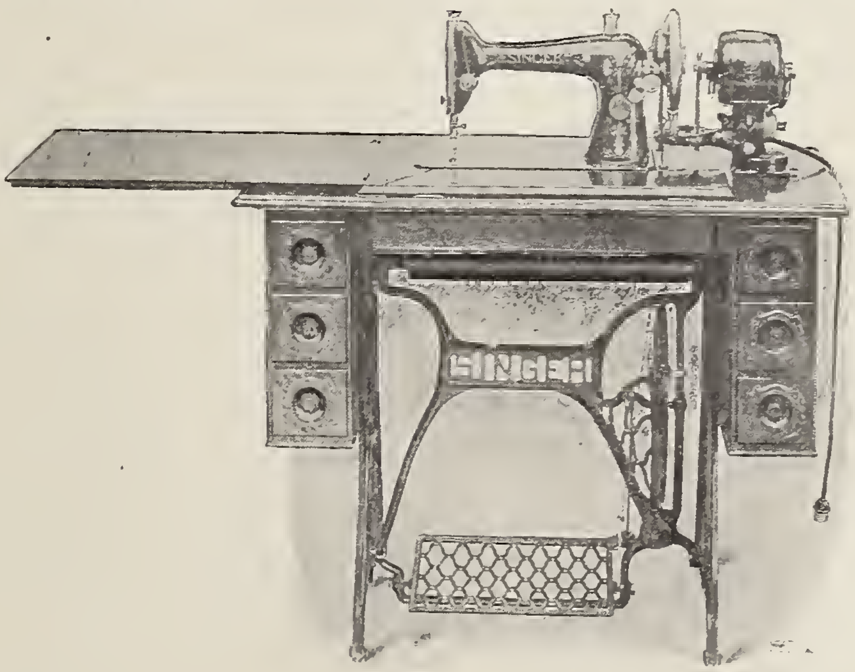


Fig. 2.

The attachment comprises simply the operating switch, cable and socket, so anyone without special mechanical or electrical knowledge can install the motor. An advantage not found in other devices of a similar nature lies in the fact that no part of the sewing-machine is disturbed in order to equip it with the electric motor, not even the flywheel connecting rod. It is only necessary to remove the belt. The motor is placed so that its shaft and the shaft of the hand-wheel are in the same straight line. Sewing is accomplished by turning the switch and depressing the pedal in the usual manner. This latter action removes the friction brake and increases the ten-

Fig. 1.

sion of the driving belt, the whole attachment rocking about the pivot which can be seen directly below the motor. When the pressure of the foot on the pedal is removed, a coiled spring in the base of the attachment causes the tension on the driving-belt to be relieved and the brake to be applied to the hand-wheel, causing the machine to stop. This method of control is so positive and simple that it is not necessary for the operator to remove her hands from her work. In

case the sewing-machine is so constructed that the pulley is on the outside of the hand-wheel, provision has been made for changing the location of the small driving pulley of the apparatus.

When it is desired to lower the head or to place the cover on a stationary head machine, the driving apparatus can be turned to one side by withdrawing the indexing pin shown close to the table. If the machine is not to be used for a considerable period of time the complete driving mechanism can be removed, leaving only the small plate, which is not objectionable in appearance.

No special house wiring is necessary for this motor, but connection is made from any lamp socket by means of a flexible cord and attaching plug.

Business Note

The *Technical Index*, a comprehensice record of current technical literature published in Belgium, announces that hereafter it will be represented in the United States by the Geo. H. Gibson Co., Tribune Building, New York City. The *Technical Index* appears monthly and gives a systematic descriptive record of all original articles appearing in over 200 engineering and technical journals and reviews, also indexing the proceedings of technical societies and technical books issued in all countries.

250-Volt Tungsten Lamps

The Western Electric Company announces that they are now in a position to furnish Sunbeam tungsten lamps in voltages between 200 and 250. The lamps are made in four sizes at present; namely, 45, 70, 112 and 180 volts. They are of the well-known Sunbeam quality, and have given up to date as good satisfaction as tungsten lamps of 110-volt range. Information and price may be obtained at the Western Electric Company's nearest branch house.

Industrial Progrces for October, published at Milwaukee, C. A. Tupper, Editor, contains: "The New Steam Turbine Plant of the Nairn Linoleum Company, N. J.," "An Ideal Steam Stamp for Prospectors," "Phosphate Mining—Distribution of Deposits in the United States," "A Modern Saw Mill and Its Equipment," "Tests of Centrifugal and Screw Pumps Installed in the 39th Street Sewage Pumping Station, Chicago," "An Electrically-Driven Copper Mill."

A New Speer Brush

Since the committee of the engineering association of the American Street & Interurban Railway have taken up the carbon brush question and expressed a desire for a higher grade brush than they had been using, the Speer Carbon Company, of St. Marys, Pa., has brought out a brush to conform with their specifications. This brush is made by a new process —perfectly homogeneous, uniform, no laminations and made in 4 degress of hardness; Grade H, Grade H-1, Grade H-3 and Grade H-8.

For the past year they have been running some very elaborate service tests on some of the largest city railways and also on the large interurban railways, and they have more thn exceeded their expectations. These tests were run on all classes of motors, regardless of the condition of the commutator or brush-holder, and a great many of these motors had brush-holders that were badly worn, as they desired to give them the hardest test possible. All these tests showed a mileage of from 30,000 to 50,000 miles.

Trade Notes

The contract for the construction of a hydro-electric development across Paulin's Kill, Columbia, N, J., for the Warren County Power Company, Meikleham & Dinsmore, Engineers, has been awarded to Frank B. Gilbreth, No. 60 Broadway, New York City.

Several large orders for direct-current apparatus have recently been received by the Crocker-Wheeler Company, of Ampere, N. J. Among these is one from the Southern Iron & Steel Co., of Roger, Ga., calling for 200 250-kw., engine type, 550-volt, direct-current generators and 275-h.p. in 500-volt direct-current motors. This is in addition to a recent order for 1450-kw. in engine-type generators and 1200-h.p. in slow-speed motors from the same concern. The Republic Iron & Steel Co., Youngstown, Ohio, placed an order for a 600-kw., engine-type, 250-volt, direct-current generator, which will be added to a plant consisting of two 300-kw. Crocker-Wheeler generators.

Personal

Mr. Ernest Gonzenbach has been elected president of the Sheboygan Light, Power & Railway Company, Sheboygan, Dis., to succeed the late Dr. F. A. C. Perrine.

Mr. C. B. Humphrey closes a valuable service of fifteen years with the Westinghouse Electric & Mfg. Company, during the last five years of which he was manager of the detail and supply sales department, to become a vice-president and director of the White Investing Company, No. 43 Exchange Place, New York City, which will undertake the financing, development and operation of enterprises based on natural resources, and deal in bonds and securities.

Among the interests of the company are the Aguacate Gold Mines in Costa Rica, which are now being developed and will be in operation in the near future; the development and operation of a slate mine for the production of slate for roofing, electrical and industrial purposes will be undertaken at once, and a number of properties of other characters acquired.

Mr. W. F. White, President of the Company, was formerly manager of the Cincinnati Edison Electric Company and later Vice-president of The North American Company.

For a number of years Mr. Humphrey was district manager for the Westinghouse Company, with headquarters at Cincinnati, and was called to the home office in 1904 to take charge of the detail and supply department, which, in recent years, has grown to an important factor in the total volume of Westinghouse business. Mr. Humphrey assumed his new duties October 1st.

Mr. Joseph F. Becker has been appointed sales manager in charge of the sales department of the United Electric Light & Power Co., New York. Mr. Becker has had several years' experience in the central-station field, and comes from the Edison Electric Illuminating Company of Brooklyn, resigning his position as general agent to take up his work in New York.

News Notes

The Moore Electrical Company, of Newark, N. J., has closed a contract for installing the Moore light in the new building of the Emigrant Industrial Savings Bank at 43-51 Chambers Street, New York, to consist of 42 tubes and approximately 4500 ft. of glass tubing.

The Ridgway Dynamo & Engine Co. has opened a district office at Cleveland, in charge of H. C. Hale.

Hydro-Electric Power Plant of the West Point Mfg. Co.

A most important water-power development and one which marks the steady progress of the South in the utilization of her large natural resources is shown in that just completed by the West Point Mfg. Co., at Langdale, Ala. The magnitude of the work is significant in itself of the awakening of the Southern manufacturer to the economic possibilities presented by the abundant water-power for the generation of electricity.

Chas. T. Main, mill engineer and architect, of Boston, Mass., designed the station and had in charge the installation of all motors except those in the Shawmut mill, also transformers and transmission lines of which the following is a description:

Langdale is situated about 35 miles above Columbus, Ga., on the Chattahoochee River. At this point the river is nearly 1600 ft wide. From the reports of the United States Geological Survey the minimum flow recorded is about 800 cu. ft. per second. Taking everything into consideration, it was decided to develop the privilege for a flow of 3000 cu. ft. per second. The normal head is 13 ft., which may be increased by the use of flash boards to 16 ft.

The power-house is built directly on a rock foundation, concrete being the material used, up to the level of the main floor. The superstructure is of brick surmounted with a cinder concrete roof supported by steel trusses. This house is 214 ft. long by 35 ft. wide.

Owing to the low head conditions it was necessary to adopt the vertical type of turbines and transmit power by means of bevel gears to the generators, which are direct-connected to horizontal jack shafts.

The total power is divided into four units, one of 750-kw. and three of 550-kw. capacity each. An engine, previously installed, will drive a 400-kw. belted generator to act as a relay. The 750-kw. unit is driven by four 60-in. "New American" turbines, built by the Dayton Globe Iron Works, Dayton, Ohio. Two of the 550-kw. units are driven by turbines of the same make. The above turbines are of the cylinder gate type, so designed as to have their racks and pinions out of water and accessible for lubrication. The remaining 550-kw. unit is driven by two Samson turbines used in the old development. The total capacity of the water wheels at 13 ft. head (without flash boards) is about 3250 h.p., which will require a flow of a little more than 300 cu. ft. per second. Each unit of the new turbine installation is controlled by a Lombard Type N governor, made by the Lombard Governor Co., of Ashland, Mass.

Excitation is furnished by two 85-kw., 125-volt exciter units driven by Morse silent chains from a jack shaft driven by two 39-in. New American turbines. Woodward governors are here used, made by the Woodward Governor Co., Rockport, Ill. The generators, including exciters and switchboard, were furnished by the Westinghouse Electric & Mfg. Co. These generators are designed to deliver three-phase, 60-cycle current at 600 volts and have sufficient capacity to maintain full load conditions at 80 per cent. power factor. Their speed is 150 rev. per min. Of the total of 2400 kw., 1400 kw. is to be available for transmission to and use at the new Shawmut mills situated two miles distant.

The switchboard upon which are all the controlling switches for the circuits to the Langdale and Shawmut mills is located near the center of the power-house in the exciter bay. Current for the Shawmut mills leaves the main switchboard at 600 volts and passes to the transformers in the tower at one end of the building where it is stepped up to 11,000 volts. At the receiving end it is stepped down again to 600 volts for use with the motors.

There are four 500-kw. transformers at each end of the transmission line, three for regular use and one for a spare. These transformers are controlled from a selector panel on both high and low tension sides, so that in case of accident the extra can be quickly cut into the place of any one of the others.

The transmission line is of No. 2 B. & S. copper wire spaced 30 in. on centers. At each end is installed a high-tension oil switch, and in addition to a set of lightning arresters a grounded galvanized cable is carried along the conduit for its entire length as a double protection. The transformers inside the power-house and all points of high tension circuit under cover are installed in separate fireproof rooms.

The lighting at Langdale is secured by transforming down from the generator current at 600 volts to the lighting voltage in the yard. All high-tension switches, lightning arresters, and all mill motors, together with their switches, auto-starters, were furnished by the General Electric Co. The transmission lines and all wiring was furnished and erected by the Carter & Gillespie Electric Co., Atlanta, Ga.

B. H. Hardaway, of Columbus, Ga., was the contractor for the station foundations and dam construction, and the J. F. Gallivan Building Co., Grenville, S. C., built the superstructure of the station, part of the dam and the small parts of the miscellaneous work incidental to the finishing of the job.

The General Electric Company Awards at Alaska-Yukon-Pacific Exposition

The General Electric Company has received grand prizes (highest award) at the Alaska-Yukon-Pacific Exposition in each class of electrical apparatus in which an exhibit was made by the Company. General Electric apparatus was ranked first in the following divisions:

Apparatus for cooking by electricity. Apparatus for heating by electricity. Automatic motor starters. Arc lamps. Bonds. Cabinets. Circuit breakers. Cutouts. Fans. Indicating instruments. Integrating instruments. Insulated wires. Insulated cables. Incandescent lamps. Mine locomotives. Motor generators. Motors for direct-current. Motors for alternating-current. Recording instruments. Rectifiers (mercury arc). Sockets. Switches. Transformers. Wiring devices.

General Electric turbines were also entered in the Government exhibit in which no awards were made.

A New Gas-Engine Company

The Sheffield Gas Power Company has purchased the entire assets, factory and good will of the former Weber Gas Engine Company at the bankruptcy sale thereof.

The factory has been in continuous operation throughout the term of the receivership, and has been continued in operation by this company without interruption, with the result that we are in position to furnish, without delay to any customer, the entire line of Weber gas engines and gas producers.

The management of the business, as well as the sales and factory departments, are in entirely new hands. George M. Hawes, the president of the company, is a graduate of the Massachusetts Institute of Technology and has been interested in machinery and electrical work for a number of years, giving particular attention to central station power plants. He has also devoted much time to gas-engine and producer design.

Freeman Field, vice-president and treasurer of the company, has devoted the past 12 years exclusively to the gas-engine business, both in the manufacturing and selling branches, and for the past seven years has been connected with the Olds Gas Power Company as general sales manager and western manager.

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NOTICE TO ADVERTISERS

Insertion of new advertisements or changes of copy cannot be guaranteed for the following issue if received later than the 15th of each month.

NOTE—For some time THE ELECTRICAL AGE has been appearing late in the month, it being impossible to bring the publication date forward. Consequently this, which ordinarily would be the November issue, appears as the December issue. The January number will issue on the 15th. Each subscriber will have his subscription advanced one month and therefore receive twelve issues.

CONTENTS

Hydroelectric Plants

One of the best papers which has been presented of late to the members of the Institute of Electrical Engineers is that by H. L. Doherty, which was read on December 16th. While full of good meat from beginning to end, special attention attaches to the proposal to use steam turbines in connection with water-powers.

It is well known that many water-powers are undeveloped because they are not sufficiently large to supply a reasonable peak load, although ample to take care of the average load. In such cases Mr. Doherty proposes to take care of the peak load by means of steam turbines kept running light and automatically regulated to take a load only when the demand exceeds the power of the hydroelectric equipment. Thus, in one case cited by the author of the paper, arrangements were made to install a large steam turbine in connection with a relatively small water-power plant, the generator of the steam turbine being designed to run as a motor, while the vacuum on the turbine blades was maintained to reduce the windage loss, with the governor of the turbine so arranged that the slightest reduction in speed would cause the steam valves to open and the turbine immediately to pick up the load.

This idea opens up a new engineering field, types of boilers, condensers, turbines, generators and regulators being required which are especially adapted to this service. Thus Mr. Doherty suggests the use of internally fired boilers on account of their small radiation loss during the periods that the entire load is carried by the hydroelectric equipment, and also on account of their ability to maintain tightness against unnecessary ventilation when run in bank. Again, the use of oil for fuel is a very promising field, especially in those districts where oil is more plentiful than coal.

This subject is one which will repay study and development, and it is to be hoped that Mr. Doherty's paper will stimulate the interest which the subject deserves.

The Institute and its Meetings

Ambitious electrical engineers, both budding and full-grown, are periodically impelled to attend the meetings of the Institute of Electrical Engineers. They adhere to these good intentions for a short time, and then backslide until a new impetus occurs. The fact is that the meetings usually are very dull and uninteresting.

The reasons for this condition are not far to seek. The first trouble is the lack of sociability at the meetings. The members are kept waiting in line, like the gallery candidates at the door of the Hippodrome, simply for an opportunity to sign their names and to be given a proof of the paper. After the meeting is over, the exhausted survivors are only too glad to get away and reach the cheer of the home hearth.

If people had an opportunity to meet and chat with former associates and acquaintances, there would be much more interest in the meetings. The Institution of Electrical Engineers of London is considerably ahead of ours in this respect. The proofs of the paper are set on numerous stands put in convenient places, and the only signatures required are those of visitors brought by members. The people thus have an opportunity to converse before the meeting. After the meeting, the members are allured into a large room by the aroma of coffee and cocoa, and enjoy a social half-hour. They are served with refreshments from a long counter covered with coffee and cocoa steamers and plates of biscuits. A number of attendants are kept busy handing these condiments to members, who carry them to distant parts of the room, where they can converse in comfort with their friends. The object of the refreshments is simply to give an excuse for a social half-hour.

Why not use the handsome foyer on the ground floor of the Engineering Building for social purposes?

The second defect of the A. I. E. E. meetings is the bad delivery of the papers and discussions. In this respect the London Institution is again superior to ours. It is very unusual to hear a member of the London Institution *read* his contribution, be it a paper or a discussion of a paper. The writer has known of meetings in London where attempts to read notes have been quickly stopped by the obvious inattention of the audience, the student members tapping time in unison with their feet! Very few people are able to read aloud and think what they are reading. They may start well, but they usually forget the sense of what they are reading in a short time, after which the reading becomes a mere mechanical process, meaning nothing to the reader and audience. The majority of the contributions to the A. I. E. E. discussions are read by men who have done their thinking at home and read their contributions at the meetings regardless of puctuation and the time required for their hearers to assimilate what is poured into their ears. This is almost an act of discourtesy, and members who make a habit of doing this deserve to be notified by the suffering audience that there is an end to the patience of the most-easily imposed upon. During the discussion of Dr. C. T. Hutchinson's paper, the audience was thus distressed by nearly every speaker, and some of the most prominent engineers in the city left their seats quite early in the evening rather than be bored for another hour or two—and this in spite of the fact that the meeting was one of the most important of the year.

The remedy for this is obvious. Let the would-be speaker think out, or even write out, his contributions, make notes of it on a card and use the card at the meeting to refresh his memory while speaking.

The members of the London Institution get an excellent training in extempore speaking during their younger years. The student members have formal meeting, where papers are read and discussed and training in public speaking is acquired at an early age. It is usual, at these meetings, to have some distinguished member as chairman.

Another source of dullness in our discussions is the excessive caution and fear of being wrong displayed by nearly all members. Editorially, we are suspicious of any man who never makes a mistake.

Production of Copper in 1908

The mine production, smelter output and refinery production in 1908 exceeded those of 1907. The production in 1908 by smelters from copper-bearing material mined in the United States was 942,570,721 pounds, the largest in the history of the industry. The production in 1906, the next largest, was 917,805,682 pounds; that for 1907 was 868,996,491 pounds.

UNITED STATES LEADS THE WORLD

The world's production of copper in 1908 was 1,667,098,000 pounds, so that the United States contributed considerably more than half the total product of the metal.

The exports of refined copper were 618,613,842 pounds, the largest amount recorded; the imports were 218,705,487 pounds, mostly from Mexico, Canada and Peru.

CONDITIONS DURING THE YEAR

The domestic consumption of new copper in 1908 was 480,000,000 pounds; of old copper, 23,000,000 pounds, making the total domestic consumption 503,000,000 pounds, against 547,000,000 pounds in 1907. The stock on hand January 1, 1908, was 125,745,796 pounds; on January 1, 1909, it was 121,876,759 pounds.

The average quoted price of electrolytic copper at New York in 1908 was 13.2 cents a pound. In 1907 the price was 20 cents a pound. The commercial conditions during the year were very stable, the variations in monthly average price covering a range of only 1.54 cents, as compared with 11.90 cents in 1907.

A notable feature of the industry was a decrease in cost of production due to improvements in methods and the increased efficiency of labor.

Steam Pipe Coloring

There has been much complication of piping in modern power stations, and much confusion has attended the failure properly to designate or identify the piping. In the larger stations the piping is usually painted according to a definite color scheme, in which each color or combination of colors indicates the fluid conveyed by the pipe. In most stations, too, the function of the pipe is plainly painted on it at intervals so that there may be no mistake about it; and usually the direction of flow is indicated by arrows.

In any particular station the identification scheme may be carried out with great definiteness, but so numerous are the classes of pipes and their corresponding colors that it requires some memory work on the part of a new employee to master them. And when he comes to accept a position in a new station he must master a new color alphabet, and endeavor to discard one which was perhaps rooted into his mind in its susceptible years. Just how much damage and errors will have to be charged up to confusion of piping colors, nobody knows; but that it is serious, and perhaps increasing with the multiplication of large stations, there can be no doubt.

Nor can there be any sound reason why a definite, uniform coloring scheme may not be agreed upon by the interested bodies. For the Institute of Mechanical Engineers to take it upon itself to settle this question were a little presumptuous in our opinion. There are a few other organizations who ought to be consulted in the matter and ought to meet by representation with the mechanical engineers' committee and thus settle the matter finally.

Electric Power Conductors

By Wm. A. Del Mar

A. C. G. I., Assoc. Mem. A. I. E. E., Assoc. I. E. E., Assistant Engineer of the Electrical Transmission Department, New York Central Railroad, formerly with the Interborough Rapid Transit Co., etc.

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D. VAN NOSTRAND COMPANY,
23 Murray and 27 Warren Streets.

This is a reference book for engineers who are interested in the choice and use of electric power conductors. It treats of the properties of conductors and insulators, the considerations determining the type and size to be used and the installation and maintenance of overhead and underground conductors.

The style might be described as "choppy," were it not perceived that every effort has been made to present a treatise brim full of concentrated data arranged for ready reference. At first sight the book seems to invite comparison with Dr. Perrine's well-known work, but the resemblance is superficial only, as there is little or nothing in common to the two works.

There are a number of features in this book which, as far as we know, are not to be found in any other. Among these are the following: The tensile strength and resistance of cables as differing from those of single conductors; a wire table based on the A. I. E. E. temperature co-efficient of 0.0042 instead of Matthiessen's variable co-efficient, which is condemned by the A. I. E. E. Standardization Report, but used in their antiquated wire table; a solution of network problems by determinants; a concise statement of the best data on carrying capacity, which includes that for short period currents; an account of a short-circuit indicator, originally described in the pages of this journal; how to calculate the potential drop in railway circuits where the Keiley circuit breaker house system is used; the calculation of potential drop in single-phase railway circuits; an exact method of calculating the potential drop in long transmission lines having capacity and leakage; blank specifications for aerial and underground conductors, written in such form that an engineer can dictate specifications by reading from the book and filling in the blanks, according to his requirements; and a method of calculating the most efficient thickness of insulation on rubber-covered conductors, originally outlined in the Electrical Age of April, 1907.

On the first page, second line, there appears a figure 0.995 for the relative specific gravity of copper and aluminum, which, from the figures for specific gravity given in the preceding line, should obviously be 3.31. This misprint at the beginning of the book led the reviewer to search carefully for others of a similar nature, but it is only fair to state that a critical search failed to reveal any other error of consequence, except on page 4, where 4×6^6 is written for 4×10^6. Beyond a few letters upside down and such vagaries of the printer, the work appears to have undergone very careful editing, which makes it very exceptional for a first edition of a work of that nature.

The main text of the book is quite free from theory (although profuse in formulæ), but the basis or theory of everything new or uncommon is given briefly in a series of instructive appendices, which lift the book from the ordinary handbook class and make it appropriate for the use of advanced students. We are, in fact, advised that it is now part of the regular equipment of the post-graduate class at the Massachusetts Institute of Technology.

The Principles of Shades and Reflectors

Dr. LOUIS BELL

This paper is intended to be merely a discussion of some of the general principles on which the use of shades and reflectors for artificial illuminants depends, without mathematical analysis and without any attempt to consider the respective merits of the many types of shades and reflectors now on the market. I hope it will, however, guide in the use of shades and reflectors, with a common sense and practical view of some of their properties which are at times misunderstood. By a shade I mean here a structure which is intended chiefly to keep the direct light of the illuminant out of one's eyes. By a reflector, I mean a structure which is chiefly intended to re-distribute the radiation into more useful directions than are available with the unmodified source.*

Of course, it is now well understood that the modern efficient light sources, whatever their character, require some screening on account of their very high intrinsic brilliancy which is very liable to injure the eyes. Many screening structures are at once shades, tending to modify this intrinsic brilliancy, and also reflectors, tending to re-distribute the light flux. Such composite structures are easily interpreted if one considers their two functions separately. To begin with the shade. The simplest embodiment of the pure shading function is a translucent screen of some convenient material that entirely, or almost entirely, covers the source so that the light, which is practically useful, passes through the screen. Perhaps the best typical form of such a shade is an opal or ground glass ball surrounding the light completely if it be an incandescent lamp, or with approximate completeness if a mantle burner. I shall here consider chiefly the incandescent merely because it can be entirely enclosed and is easily used in reflectors of any shape. The normal distribution of the light from an incandescent lamp may be compared to a rather flattened apple, of which the socket is at the stem end and the tip of the lamp at the blossom end. A vertical section shows for a 16 c-p. carbon lamp approximately the form displayed in Fig. 1. It will here be observed that the rated candle-power is in the horizontal plane, but the candle-power at the tip is commonly down to between six and seven, and that at the socket almost negligible, being only such light as is emitted from the outer portions of the filament, or, like the filament, reflected and refracted upwards by the glass of the bulb, which is of somewhat greater extent than the socket. Now, imagine this lamp enclosed in a clear glass sphere, say 6 in. in diameter. The effect on the distribution light about the lamp is almost negligible, since the light proceeds in all directions with very little obstruction and with only such slight diffusion as comes from dirt on the globe. The net effect of this is merely a very slight rounding of the curves, hardly perceptible and entirely trivial from a practical standpoint.

Now, suppose that we take this ball and sand blast or etch it very lightly upon the outside; then a ray of light which reaches this surface from any

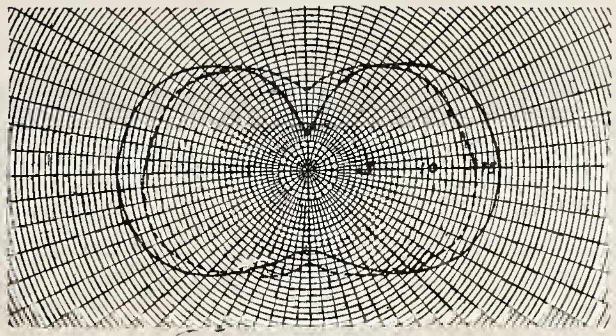


Fig. 1

point of the filament passes through with comparatively little obstruction, but is to a certain extent broken up and scattered by the innumerable fine irregularities that make up the roughened surface. Perhaps no more than 10 per cent. of the light may be actually obstructed in passing through the surface and turned back at it. A similar amount may be scattered at the surface of emergence, which therefore looks somewhat bright and becomes a secondary source of illumination from which light is scattered in all directions. The effect of this scattered light is slightly to round out the typical distribution curve of the bare lamp, and the actual distribution thus produced about a lightly sand-blasted ball is shown by the dotted curve of Fig. 1. This curve lies inside the original one at all points except those very near the socket and the tip, where the original illumination is weakest.

The actual loss of light flux in passing through diffusing balls may range from hardly more than 10 per cent., where the surface roughening is very slight, up to 50 or 60 per cent. in the case of very dense sand blasting or a globe of milky glass. The apparent brightness of the surface due to diffusion is approximately proportional to the light lost in passing through the wall. In the case of such shades, then, one deliberately sacrifices 25 per cent. or so of the total luminous flux, in order to completely avoid the dazzling effect of the source of the light itself.

On account of the tendency of the iris to stop itself down automatically in the presence of a bright source of light, the gain from such diffusion is often greater than the loss through absorption. Other materials than glass or porcelain may be and often are utilized to this same end, especially in ornamental screens which are made of textiles, translucent paper and the like. The losses in such shades are generally greater than those in glass or porcelain owing to the presence of greater real absorption in translucent walls. A shade of tracing cloth, for example, would certainly cut off from 35 to 40 per cent. of the light, and a shade of ordinary tissue paper, or thin silk, even more, while the loss of light with colored paper or textiles is likely to rise to 75 per cent. or more, owing to selective absorption. Such shades therefore are chiefly of decorative value, although their use in cutting down intrinsic brilliancy may at times be important.

It can be seen therefore that none of these pure shades are of much importance as mere distributors, but are used as the name implies, although if they intercept a considerable amount of light in such a way as to produce strongly diffusing surfaces they tend somewhat toward a spherical distribution. The chief practical matter in selecting them is to secure the proper degree of density, just enough to cut down the intrinsic brilliancy of the source to a point where it will cease to be annoying. Ground glass and opal globes dense enough to cut off, say, 20 or 25 per cent. of the total flux generally fully meet this requirement.

The case of reflectors, that is, devices which are chiefly intended to re-distribute the light, is a much more intricate one. The general purpose of a reflector is to intercept some or all of the light flux which would naturally pass off in a useless direction, and turn it into a useful direction. In the case of most reflectors used in practical illumination, the purpose is to intercept the light which would otherwise pass above a horizontal plane, or a surface depressed somewhat below the horizontal plane, and turn it into useful downward angles. Primarily the simplest case is to arrange a reflector to intercept the light above the horizontal axis of Fig. 1 and turn all or the major part of it into the downward hemisphere.

*I. E. S. 1909.

The simplest possible case of a downward reflector is that of a flat reflecting plate placed above the source of light at some convenient distance. Fig. 2 shows a diagram of this arrangement in which the plate *ab*, or radius *l*, is placed at distance *l*, horizontally above the source of light, *c*, which is here temporarily supposed to be a point. So supposed *ab* intercepts all rays passing upward within a spherical angle of 90 degrees. A ray from *c* at r_1 just touches the periphery of the reflector and leaves it at an angle of 90 degrees with its original direction and at an intensity which is *k* times its incident intensity where *k* is the coefficient of reflection. Any ray just outside of the spherical angle of 90 degrees misses the edge of the reflector, and the distribution of the source determines its intensity.

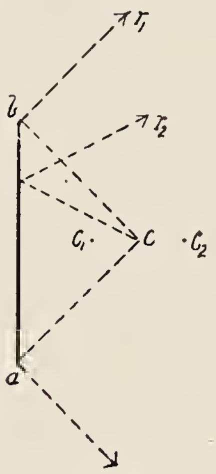


Fig. 2

Any ray falling on the reflector nearer the center than r_1, as r_2, has its direction changed by reflection less than 90 degrees, and is subject to the same change in intensity before mentioned, *k* being generally slightly diminished.

All the reflected rays, therefore, fall within a spherical angle of 90 degrees below the horizontal, so that as the ultimate distribution from the source and its reflector, one would have in the zone 45 degrees above and below the horizontal distribution of the lamp. At angles below the horizontal greater than 45 degrees the original distribution would be re-enforced by the reflected rays. The distribution more than 45 degrees below the horizontal would therefore be strengthened and rendered more nearly a segment of a spherical surface. There would be, however, a zonal hump at 45 degrees below the horizontal where the reenforcement from reflection begins. Suppose, now, the source *c* be moved nearer to *ab*, to a position c_1. A larger spherical angle of upward light will now be reflected, and the extreme rays reflected will take a path nearer to the horizontal, spreading out therefore the reflected component and producing a widened lower distribution approximating the lower half of an oblate spheroid. The spreading out effect will also tend to reduce the hump referred to and distribute the light more uniformly. Removing the source of light further from the reflector to a point c_2 produces the opposite effect, picking up slightly less light by reflection and throwing it more downward.

In the case of a practical reflector the long filament may be considered as composed of a line of radiant points along the axis of the reflector, each adding its own component to the reflected light on the principles just laid down. The larger the reflecting plate, compared to the distance of the source from it, the more light will be turned down and the more widely it will be distributed. If the plate is not quite flat, but forms a very shallow cone, the extreme rays will be cut off slightly, but the general effect will be about the same. Very many practical reflectors are merely simple modifications of this flat, or slightly coned, reflecting plate, and they obviously all belong to the general type of distributing reflectors. In fact, most distributing reflectors have been made on this principle. The chief part of the light distributed is that due to the lower hemispherical distribution of the lamp, the effect of the reflector, if fairly wide, being merely to turn down rarely as much as half of the light in the upper hemisphere, and to scatter it over the lower hemisphere without great change in distribution. The ordinary distributing reflector, therefore, does not distribute to any considerable extent in the sense of changing the distribution, but merely somewhat increases the volume of light below the plane of the shade, and obviously, unless the lamp itself has a ground glass bulb, the glare is in no way reduced. Hence such a reflector is a good deal of a humbug from the standpoint of proper illumination, although not without its uses. Surfaces are often corrugated or slightly matt to avoid streaky reflections of the filament, but this does not help the extreme intrinsic brilliancy of the filament. If wide distribution is necessary, as sometimes it is, it is better obtained by a combined shade and reflector which will more effectively screen the lamp.

Fig. 3 shows in diagram another kind of reflector which is decidedly more useful, the familiar reflecting cone. As shown in section, *ab* is a 90-degree cone with the radiant point *c* in the plane of its open end. In this case a ray as r_1, which just touches the edge of the cone, is reflected at right angles from its original direction straight downward. A ray which falls normal to the surface of the cone, as r_2, is reflected parallel to the opposite face of the cone, while rays which are twice reflected, as r_3, and hence considerably weakened, pass out of the cone at an angle between the limiting angle of r_1 and the limiting angle of r_2. The angle of distribution is approximately that of the sides of the cone, barring diffuse reflection, and the device acts as a powerful concentrator. The loss of light in reflection, other things being equal, is slightly greater than in the case of the flat shade, because part of the rays are twice reflected. Moving *c* toward the vertex of the cone evidently would permit r_1 and r_3 to diverge a little, while at the same time reflecting a larger proportion of the flux. Mov-

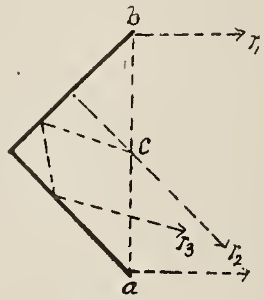


Fig. 3

ing *c* in the opposite direction causes the brilliant rays of r_1 to converge a little, at the same time letting out some light above the horizontal.

Inasmuch as rays of the general character of r_1 predominate in using an ordinary lamp within the cone, the result of the reflector is to produce a strong downward increase of light, although the curve has shoulders produced by rays corresponding more nearly to r_2 and r_3. As a spherical angle of the reflector, with respect to the mean position of the source of light in the filament, exceeds 180 degrees, the redistribution of light is very marked, and shades of this general type are well known and effective concentrators, which, when placed fairly low, also screen the lamp from direct vision. The ordinary green flashed opal shade so largely used in reading-rooms is an excellent and extremely useful example of this type. Distribution can obviously be somewhat modified by the position of the lamp in the shade, and is on the whole smoother and better when the lamp is fairly well up in the shade.

In either of the cases just referred to, one can obviously figure the approximate distribution on paper easily, but the computation is too intricate for ordinary use.

Fig. 4 is introduced merely as a special case in which the result is easily computed. It is a section of a hemispherical reflector with a central, or nearly central, radiant point *c*. Here each ray travels back on its own path from normal incidence, and the total downward hemispherical result

is the same as would be produced by adding the upper hemispherical distribution reduced by the coefficient of normal reflection *k* to the lower curve, as I have done in Fig. 5. It is chiefly interesting merely as showing the superior limit of added lower hemispherical candle-power that can be due

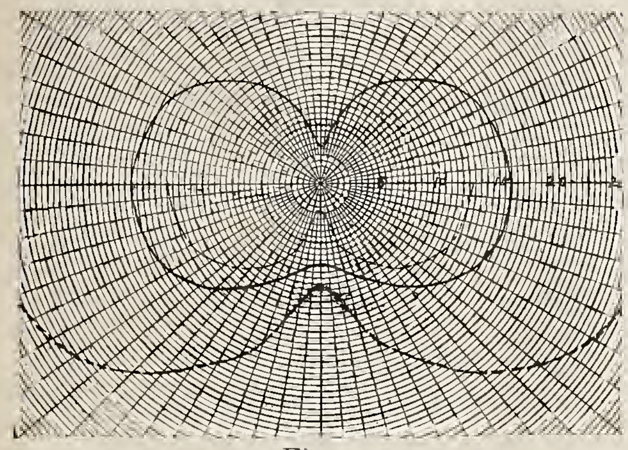


Fig. 4

any reflector. For each reflected ray undergoes minimum loss for a given assumed value of *k*, since no ray is reflected twice.

Fig. 5 shows the ordinary distribution of the lamp in the solid curve. I have assumed a coefficient of reflection of 80 per cent., and the candle-power turned downward from this hemispherical reflector would then be represented by the fine dotted curve. The coarse dotted curve is the polar diagram resulting from the superposition of this added candle-power upon the original lower hemispherical distribution. So far as increase in lower hemispherical candle-power is concerned, no reflector having a coefficient of reflection near 0.8 can do better than this for the reason just stated, however much of the light may be concentrated in certain directions. For extreme concentration a parabolic reflector with the source of light in the focus is of course the theoretically correct thing, and this is the device used in searchlight practice.

As regards the actual coefficients of reflection of surfaces used for shades or reflectors, they are usually rather low; even a first-class mirror silvered on the back and kept clean seldom gives as high as 80 per cent., except under laboratory conditions. Metals, paints and enamels fall far below this, some of them down to 50 per cent. or less, as the subjoined table shows. Diffusing coatings which, as previously stated, tend to scatter the light over a wider surface than is given by the same shape of non-diffusing reflector, may have absolute coefficients of reflection quite as large as substances which reflect regularly. Few regular reflectors naturally turn back as much of the light as falls on them as dead white blotting paper or white bristol board. There is then no loss in using a diffusing reflecting surface, provided it is kept clean; the whole difficulty is in keeping it clean.

A word now with respect to prismatic glass as a reflector. As is well known, prismatic glass acts, so far as it serves as a reflector, in virtue of total reflection in the prisms into which the glass surface is subdivided.

Fig. 6 shows a prismatic glass body, *ab*, upon which light from a source *c* falls. The surface *ab* may be taken as a section from a pagoda shade. We may divide the rays proceeding from the point *c* into three groups; of which one enters the elementary prisms of the reflector, is twice totally reflected at the prismatic faces and emerges at no more than a small angle with its original course, to all intents and purposes just as if it had been reflected from a mirror surface. If the prism surfaces were perfectly smooth, the loss of light in such a ray would practically be due almost entirely to the loss by reflection at the glass surfaces as it enters and emerges from the glass carrying the prisms, a loss determined by the angle of incidence and the angle of refraction of the glass, but with clean surfaces never exceeding a few per cent. These rays, as r_1, are in the great majority in a properly designed prismatic reflector.

A secondary group of rays, however, from each radiant point will enter the body of the glass at an angle which will not permit of total reflection. Such rays, therefore, are refracted by the prismatic surface and pass out at an angle without reflection at least to any material degree. Such rays, as r_2, lessen the completeness of the reflection as a whole, but serve a

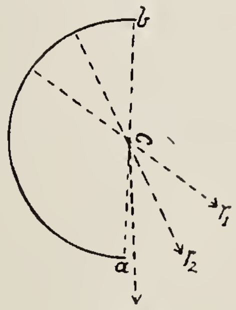


Fig. 5

useful purpose of their own in distributing the light. Finally some rays, as r_3, enter the glass at a proper angle, but strike in the corner of the prism, where the angle is never absolutely sharp, and pass through with more or less scattering from refraction. The total effect of such a plate of prismatic glass is therefore to act as if it were slightly translucent, like a very thin silver film reflecting a large proportion of the light and letting some through. As a reflector its virtual coefficient is not widely different from that of other reflectors, but the absorption, if the glass is clean, is comparatively small, probably between 10 and 15 per cent. only, so that the light, which is not reflected, gets through with this comparatively small loss. The rays of classes r_2 and r_3 are very obvious when one puts a light inside a pagoda reflector. They pass out at all sorts of angles and form a somewhat irregular distribution, suggesting in a general way the ordinary distribution of the source through the same angle. These rays form the upper lobe in the familiar distribution

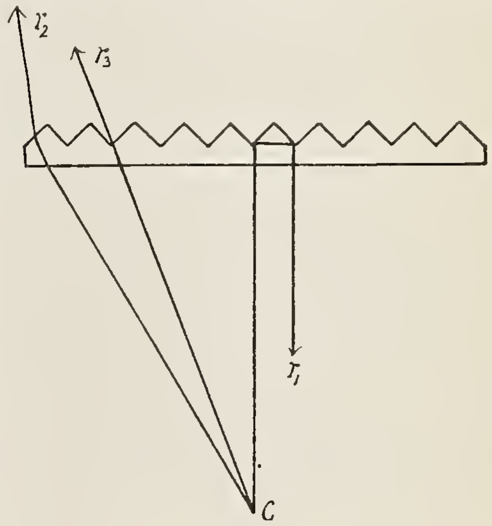


Fig. 6

curves given by prismatic glass reflectors. The effect is much the same as if the reflector were slightly translucent, but possessed of a high surface coefficient of reflection. In the Holophane prismatic glass of the original form much of the distribution was effected by altering the direction of the rays through pure refraction, sometimes with an additional element of total reflection as well.

Now, what happens when an exterior diffusing surface is given to prismatic glass? If one merely etched the surface of the prisms very slightly so as slowly to roughen them, the effect on rays of class r_1 would be to let through a certain proportion without undergoing total reflection, which proportion would be scattered at the diffusing surface, each element of which would then become a secondary source of very faint illumination. The rays the classes r_2 and r_3 would also undergo slight diffusion, so that the net effect of a barely perceptible film would be to increase slightly the apparent translucency of the shade and to decrease the directed portion of the light flux which is turned into definite directions according to the design of the prisms. An increase in the density of the etching, making a rougher diffusing surface, tends considerably again to cut down the rays which are directed by reflection or refraction, and to add to the practically uniform diffused component. The further the etching or sand-blasting or other roughening is carried, the less light

will be reflected, and the more scattered by rays not reflected and passing through the diffusing surface.

As the density of the etching increases, therefore, the direct element of illumination is decreased, and the pure diffusion which always tends to add a roughly spherical distribution is increased, so that the final result of the distribution in, let us say, a prismatic ball, whether designed to concentrate the light or to spread it widely, will be substantially the same as if the prisms did not exist and the structure were merely a smooth sand-blasted sphere. The effect of such a ball of densely etched prismatic glass would be practically the same as that of the etched ball without the prisms. Just the same reasoning holds for prismatic glass shades which are not closed, but, as usual, open at the end. If they start with a design that makes them extremely effective concentrators, then the addition of a diffusing surface either inside or outside will, according to its density, render the shade somewhat less concentrating, and if the etching or other provision for diffusion be carried far enough, the distribution obtained will be practically the same in all respects as if the shade were of opalescent glass without prisms. Similarly if the original shade was intended as a wide distributor, assuming this distribution to be obtained by the prisms and not by merely exposing the bulb of the lamp, the effect of the etching, or otherwise provided diffusing surface, will be again to weaken the directed element of the illumination and strengthen the pure diffusion effect, which again tends toward a roughly spheroidal distribution; and finally the distribution, in so far as effected at all by the shade, will approximate that obtained by a simple translucent shade. As diffusion increases, both the concentrator and the distributor would approximate to the same form of distribution.

Hence, if the valuable properties of prismatic glass for distributing the luminous flux are to be as far as possible retained, any diffusing surface given the shade should be merely dense enough to avoid the brilliant streaks due to the proportion of rays that get through the shade without total reflection, and should not be carried far enough to reduce the shade to a uniform diffusing surface. This compromise density is in fact quite easily obtained, the result being to eliminate bright streaks and to convert an otherwise strongly concentrating or strongly distributing shade into one or more moderate angles as regards the main body of the light delivered by it. Any shade or reflector in which the liberal provision is made for scattering the light, whether by sand-blasting, a diffusing coating or minute corrugations, produces the same tendency to revert to a generally spheroidal distribution. In the same way any shade of translucent material like porcelain, however the inner surface may be designed to distribute the light, lets through a nearly uniform distributed component, stronger and stronger as the translucency is more marked. It must not be understood that there is any particular objection to such a regularly transmitted component, inasmuch as it tends to give a certain amount of general illumination in a room in addition to the directed illumination which the shade is intended to produce.

Efficiency of Motor-Generators vs. Synchronous Converters

F. M. FARMER

The principal part of the apparatus in use in this country for converting alternating to direct current is included in two classes, namely, motor-generators without step-down transformers and synchronous converters with step-down transformers.* There are two standard types of motor-generator equipments and three of synchronous-converter equipments, as follows:

MOTOR-GENERATOR EQUIPMENTS

1. Generator with induction motor and without step-down transformers.
2. Generator with synchronous motor and without step-down transformers.

SYNCHRONOUS-CONVERTER EQUIPMENTS

1. Synchronous converter with induction regulator and step-down transformers.
2. Synchronous converter with synchronous booster and step-down transformers.
3. Split-pole synchronous converter with step-down transformers.

*N. E. L. A., 1909.

It is now generally conceded that 25-cycle converters are entirely satisfactory, but the use of 60-cycle converters is practically restricted to railway loads, since, as a rule, it has not been found possible to obtain satisfactory operation on the lower voltage required for lighting and power work. Motor-generator sets, on the other hand, operate equally well on both 25 and 60 cycles, and with practically the same efficiency. Synchronous converters operating on 25 cycles and motor-generators operating on 60 cycles may very properly, therefore, be compared, since each would then be operating under normal and favorable conditions.

Through the courtesy of the Edison Electric Illuminating Company of Brooklyn, and the Edison Electric Illuminating Company of Boston, in furnishing the apparatus, assistance, special wiring, and the like, the Electrical Testing Laboratories has made a series of tests on 60-cycle motor-generators and 25-cycle synchronous converters under normal commercial conditions. The principal object of this paper is to present the results of these tests, but as the subject is one of considerable importance and of general interest, it has been thought desirable to include a brief discussion of the merits and demerits of the different types from standpoints other than that of efficiency. The latter part of the paper is devoted to such a discussion.

Before taking up the tests, a brief outline of the principle of each of the five types of conversion apparatus indicated will be given.

MOTOR-GENERATOR EQUIPMENTS

As the name indicates, this apparatus is made up of two machines, an alternating-current motor directly connected to a direct-current generator. The motor may be either induction or synchronous and is operated directly from the high-tension supply system. The equipment operates practically as if driven from a prime mover, the direct-current voltage being entirely independent of the alternating-current supply.

SYNCHRONOUS-CONVERTER EQUIPMENTS

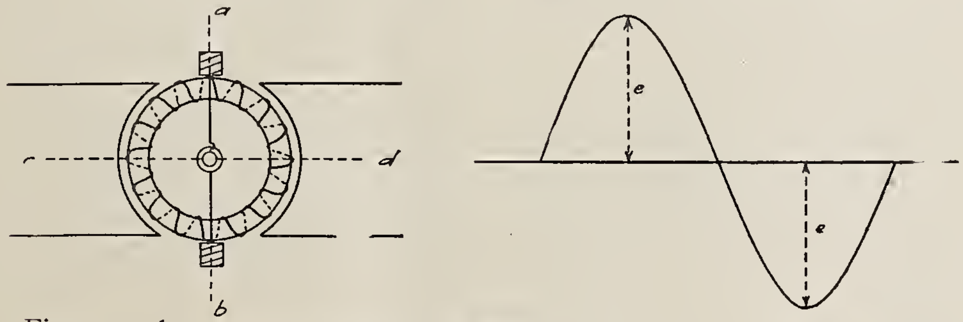
Synchronous-converter equipments include three essential elements—step-down transformers, synchronous converter, and means for changing the ratio of alternating voltage to direct voltage.

The synchronous converter is practically a direct-current machine, the armature of which is connected at suitable points to the alternating-current supply through step-down transformers. In the simple converter the direct voltage is dependent only on the alternating voltage, the ratio of the two being practically fixed and not materially affected by changes in the field excitation or in the load. Since, however, direct current must be supplied to the system at different voltages in order to take care of the varying drop on the feeders, and since the voltage of the alternating system must remain constant, it is necessary to provide some means of changing the direct voltage. It is in the method of obtaining this change in the ratio that the essential differences in the three types of equipment are found. The three methods of obtaining voltage variation are:

(*a*) Use of induction regulator.
(*b*) Use of synchronous booster.
(*c*) Use of split poles.

The theory of each of these methods will be simplified by a review of the conditions existing in the armature of a simple two-pole machine.

Let Fig. 1 represent the simple case of a two-pole double-current generator with a distributed winding on its ring armature. It is evident that the electromotive force at the rings at any instant is the sum of the electromotive force being generated in the several conductors between the taps. When these taps are in a vertical line, *a, b,* the electromotive force is a maximum, and when in a horizontal line, *c, d,* the electromotive force is a minimum or zero. A curve plotted between volts as ordinates, and positions of the taps throughout the revolution as abscissæ, will be of the general form indicated in Fig. 2. Its exact form will depend on the distribution of the winding and the distribution of the flux throughout the air gap. If the armature winding is uniform and the magnetic lines are horizontal and uniformly distributed from the top to the bottom of the armature, the electromotive force at any instant will be proportional to the sine of the angle and the resultant curve will be a sine wave. Now, if the brushes on the commutator end of the machine are set on the vertical line, it is apparent that the electromotive force will be equal to the maximum of the alternating electromotive force—that is, *e* in the curve—and any change in the amplitude of the wave form or in the curvature at the maximum value will change the direct voltage.



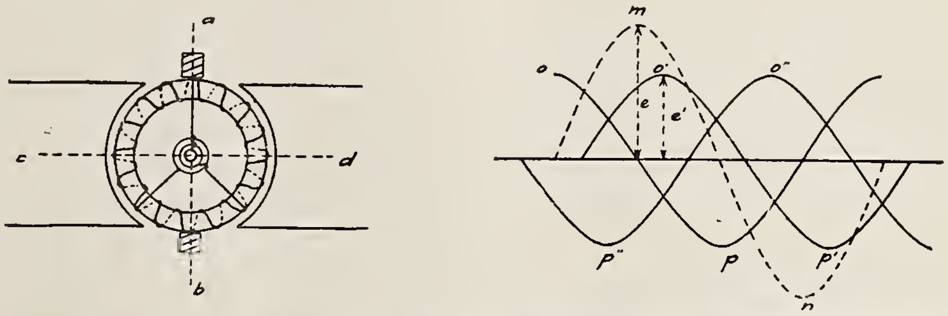
Figs. 1 and 2.—DIAGRAM AND WAVE FORM FOR TWO-POLE GENERATOR WITH DISTRIBUTED WINDING

Let Fig. 3 represent a machine similar to that in Fig. 1, except that two additional rings have been added which connect to two points in the winding 120 degrees each way from one of the original taps. When driven as a double-current generator, a single-phase electromotive force will be generated as before, having the wave form *m, n,* (Fig. 4) and in addition three other electromotive forces between each of those rings that are 120 degrees apart. These latter wave forms will of course be of smaller amplitude and may be indicated by the curves *o, p, o′ p′* and *o″ p″*. The direct voltage will be as before, equal to *e* of the single-phase electromotive force wave form.

Let the three rings that are 120 degrees apart be connected to a three-phase source having the same frequency and voltage as the machine would have when operating as a generator. The machine will then operate as a synchronous motor without appreciable mechanical load, or synchronous converter. There will exist in the armature winding various electromotive forces, including impressed and counter electromotive force in each of the three-phase circuits, equivalent impressed electromotive force and a generated electromotive force in the singel-phase circuit and the direct electromotive force.

In all cases the counter or generated electromotive force is constant because the field strength and speed are constant. If the three-phase impressed electromotive force is increased, a lagging wattless current will flow, and the inductive drop which it causes will be 90 degrees behind this current and approximately in phase with the counter electromotive force. Consequently, an increase in the single-phase voltage and therefore in the direct voltage will follow. Conversely, a decrease in the impressed electromotive force will cause a leading wattless current to flow, and the resulting inductive drop will decrease the counter electromotive force, thus decreasing the direct voltage.

The function of both the induction regulator and the synchronous booster is to increase or decrease the impressed voltage and thereby bring about the desired change in the direct voltage in the manner described.



Figs. 3 and 4.—DIAGRAM AND WAVE FORM FOR TWO-POLE GENERATOR WITH TWO ADDITIONAL RINGS

Synchronous Converter with Induction Regulator

The converter equipment using an induction regulator to obtain variations in direct-current voltage is the form in most general use at the present time. It is essentially an induction motor with a distributed secondary winding which can be locked in any position and which is connected in series between the low-tension side of the step-down transformers and the rings of the converters. With three or six-phase converters, the secondary winding of the regulator is divided into three or six separate and independent windings, each being connected in series in the proper line.

When the movable member is in such a position that each phase of the secondary winding is directly opposite the corresponding phase of the primary winding, the induced secondary electromotive force being 180 degrees behind, will oppose the primary or line electromotive force and minimum

voltage at the converter rings will be obtained. As the rotor is moved, the phase angle between the primary and secondary electromotive force will decrease from 180 degrees to zero degrees where the maximum voltage will be obtained. Thus the amplitude of the line electromotive force wave is increased or decreased as desired. This apparatus is quite separate from the converter and, except for considerations of convenience and economy in wiring, may be placed anywhere in the station.

Synchronous Converter with Synchronous Booster.

In this type of equipment, which has only recently come into commercial use, the impressed alternating voltage is increased by means of what is practically an alternator in series with the line and the converter. This alternator, or "booster," as it is called, has the same number of poles as the converter. The armature winding is connected in series with the converter armature between its rings and winding, each phase of the booster armature winding being separate and independent of the other phases. The electromotive force generated in each phase is simply added to or subtracted from the line voltage of the phase to which it is connected, as in the induction regulator. As a rule, the booster armature is mounted on the same shaft and close to the converter armature, and the field frame is supported on the main bed frame. It becomes, therefore, practically a part of the converter, although it need not necessarily be so.

Synchronous Converter with Split Poles

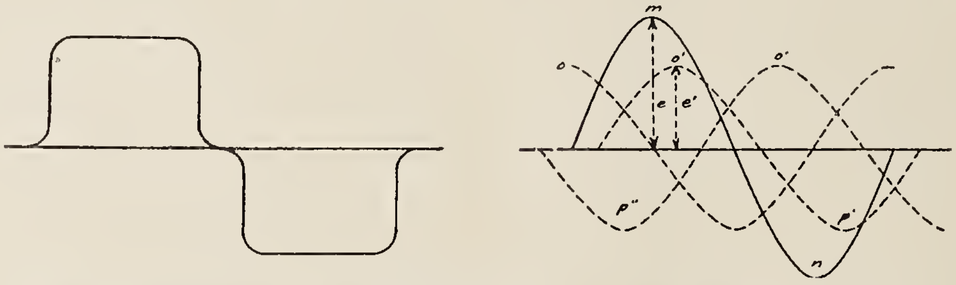
It has already been indicated that the direct-current voltage of a synchronous converter can be increased by increasing only the maximum ordinates of the single-phase electromotive force wave. This increase must be accomplished without materially affecting the counter three-phase electromotive force wave form. The split-pole converter is designed to accomplish these results and is the most recently developed of the three forms of converter equipment. As indicated by the name, a special form of field pole is used, hence in this equipment there are only two pieces of apparatus, the bank of step-down transformers and the converter.

There are two forms of the split-pole converter—the three-part and the two-part. In the former each pole is divided into three equal parts, each having two coils. The three larger coils are connected in series—thus acting as one pole—and provide the principal part of the excitation. The smaller coils are also connected in series but in such a way that the two outer coils magnetize in one direction, while the middle one magnetizes in the opposite direction. The effect of this arrangement of poles is as follows:

Fig. 5 represents the distribution of flux across the pole face when the auxiliary coils, as they are called, are not excited, and *m, n,* in Fig. 6, illustrates the corresponding single-phase electromotive force curve with a maximum electromotive force, *e*, equal to the direct voltage. When the two outer poles are excited in the same direction and the inner pole in opposite direction to the main poles, the field form may be indicated by Fig. 7. In Fig. 8 the normal single-phase wave form, *m, n,* is shown changed to *m′ n′*, and the original maximum electromotive force or direct voltage, *e* to *e′*. That this change must occur will be seen when it is remembered that at any instant the electromotive force is equal to the sum of those in all the conductors. Hence, at the position of the armature where maximum single-phase potential is obtained, although the increase in flux indicated by *x* is counteracted by that indicated by *y*, there is still a net increase due to *s*. On the other hand, the three-phase voltages are not affected because between taps 120 degrees apart only two of the three lobes of flux are included, and they, being equal and opposite, neutralize each other and produce no material effect on the three-phase counter electromotive force.

Decreased direct voltage is, of course, obtained by the opposite procedure, *i. e.,* magnetizing the outer sections in opposition to the main field and the middle section in the same direction as the main field. The corresponding field form and electromotive force wave forms are shown in Figs. 9 and 10, respectively.

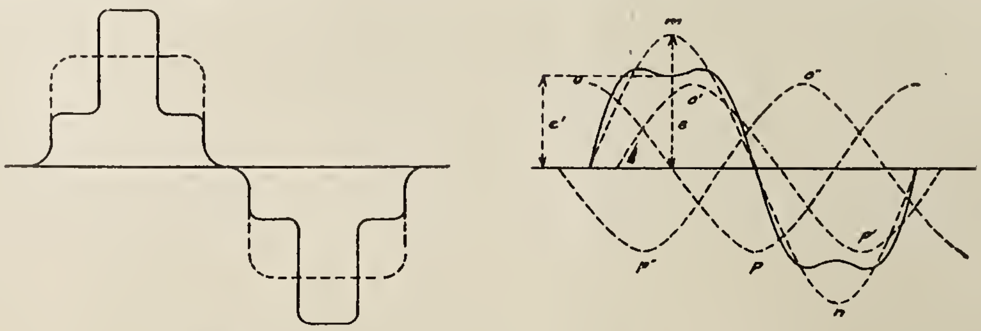
The two-part poles consist of a main section of about 90 degrees arc and an auxiliary section of about 30 degrees arc and about 30 degrees from the main section. For normal direct voltage the auxiliary pole is unexcited, while for increased direct voltage the auxiliary pole is magnetized in the same direction as the main pole. To decrease the direct voltage the auxiliary pole is reversed. It will be noted that in the three-section pole the effective width of the field form remains practically constant, while in the two-section pole the effective width is altered.



Figs. 5 and 6.—FLUX DISTRIBUTION AND WAVE FORM WITH AUXILIARY COILS NOT EXCITED

The theory of the two-section split-pole converter may be explained as follows:

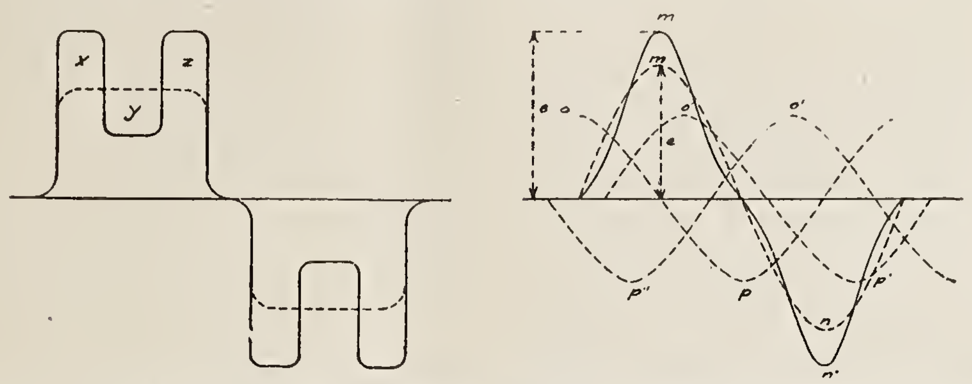
In Fig. 11 let *o m* represent the maximum counter electromotive force generated in one of the three phases in the converter when only the main pole is excited. The field form under such conditions may be indicated by (a) in Fig. 12, where ordinates represent flux density and abscissæ represent distances along periphery of armature. Since this main pole is not over 90 degrees wide, the maximum of the electromotive force wave between 180-degree taps on the armature will be the same as that between the three-phase taps, and the direct voltage will therefore also be equal to *o m.* Similarly, if only the auxiliary pole is excited, an electromotive force will be generated by the field form shown in (b). This electromotive force may be represented in both value and phase relation by *o n* (Fig. 11), which forms an angle with *o m* equal to that between the centre lines of the main and auxiliary poles, respectively.



Figs. 7 and 8.—FIELD FORM AND WAVE FORM WITH OUTER POLES EXCITED IN SAME AND INNER POLE IN OPPOSITE DIRECTION TO MAIN POLES

The corresponding direct voltage will also be *o n*.

When both pole sections are magnetized, the field form indicated in (c) (Fig. 12) will be the result, and the



Figs. 9 and 10.—FIELD FORM AND WAVE FORM WITH OUTER POLES EXCITED IN OPPOSITE AND INNER POLE IN SAME DIRECTION AS MAIN POLES

resultant alternating three-phase electromotive force will be *o r* (Fig. 11), while the resultant direct voltage will be the algebraic sum of *o m* and *o n* or *o d*. Since, however, the alternating counter electromotive force must remain practically equal to the im-

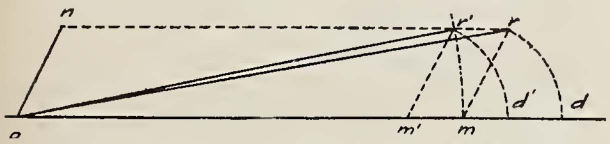


Fig. 11.—THEORY OF THE SPLIT-POLE CONVERTER

pressed, the resultant *o r* must be decreased. This is done by decreasing the excitation of the main pole an amount such that *o r* is reduced to *o r'*, which is equal to *o m*. The direct voltage is thereby reduced from *o d* to *o d'*, but it is still higher than normal by the amount represented by *m d'*.

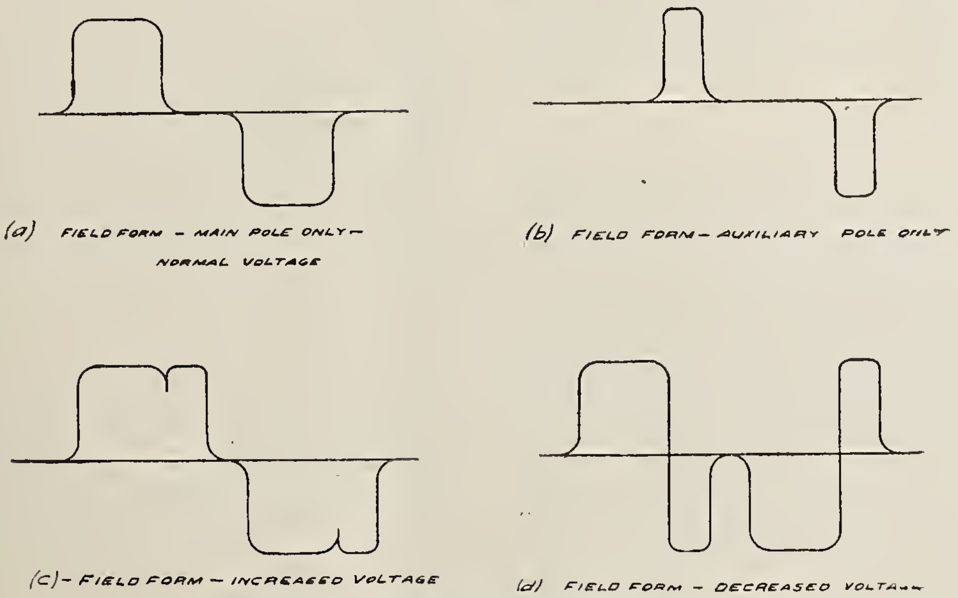


Fig. 12—FIELD-FORM CURVES

Similarly, a decrease in direct voltage is obtained as a result of the field form (d) (Fig. 12), by the reasoning indicated in Fig. 13.*

*For further discussion of split-pole synchronous converters see J. L. Woodbridge, *Proceedings* American Institute of Electrical Engineers, June, 1908; F. D. Newbury, *Electric Journal*, November, 1908, and general discussions in *Proceedings* American Institute of Electrical Engineers on Mr. Woodbridge's paper.

The alternating voltage impressed on converters is sometimes varied by changing the ratio of the step-down transformers by cutting in or out primary or secondary turns by some switching device. This method is practically obsolete, as with transformers of any but small size switching on the low-tension side is not practicable on account of the large currents and on the high-tension side on account of the high voltage. Furthermore, in lighting work, the flickering due to shifting the switch would not be tolerated.

In railway work, compounding is sometimes effected by putting an inductance coil in each phase between the step-down transformers and the rings. Increasing the field strength causes a leading current to flow, and the inductive drop in the coils being 90 degrees behind the current combines, under such a condition, with the impressed electromotive force of the converter and produces the same effect as an increase in the impressed voltage, *i. e.*, an increase in the direct voltage. Generally this scheme is made automatic by putting a series winding on the converter. For lighting work this method is not desirable, because the range in direct voltage is limited and its variation is effected at the expense of power factor.

EFFICIENCY TESTS

Tests were made on a 1000-kw unit of each of the five types of conversion apparatus described. The synchronous converters were in regular commercial service on the system of the Edison Electric Illuminating Company of Brooklyn, and the motor generators were in regular service on the system of the Edison Electric Illuminating Company of Boston. The tests were made to determine the efficiency at various loads of the complete equipment from the high-tension supply to the direct-current 'buses. All of the equipments operated under the same nominal conditions, *i. e.*, three-phase, 6600 volts alternating current to 250 to 275 volts, three-wire direct current.

Method

The tests were made by the input-output method. Since all of these machines were in regular service this was the only method available, for no change in the wiring or connections

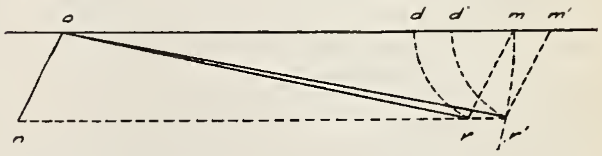


Fig. 13.—THEORY OF THE SPLIT-POLE CONVERTER

that would prevent the machine from being used on the station load was permissible. The objection may be made that such a method is a poor one. since the accuracy of the results is equal only to that obtainable in the measurement of the differences between two large quantities. For example, with instruments of an accuracy of 0.5 per cent. the efficiency of a generator receiving 100 kw. and delivering 90 kw. might be assigned any value from 89 to 91 per cent. If the lost energy, *i. e.*, 10 kw., were measured directly, the efficiency would be between 89.95 and 90.05 per cent. In other words, an error in the latter method of plus or minus 10 per cent. is equivalent to an error in the former method of plus or minus 0.5 per cent. But any method depending on the direct determination of the losses must be used under laboratory conditions, which are far from those existing in regular commercial service. Furthermore, by careful selection of instruments as to suitability, size, and the like, and by paying special attention to their calibration, there is no doubt that the method is capable of yielding results quite as accurate and reliable as commercial conditions of variable load, frequency, voltage, ratio, temperature, and the like, will warrant.

Instruments

Both indicating and integrating instruments were used in the tests. The integrating meters were used in the

manner that rotating standards are used, *i. e.*, noting the revolutions of the discs in a given time. In order to eliminate the error in the measurement of the time so far as efficiency was concerned, the two integrating meters were placed sufficiently near to each other to enable the observers to note the revolutions of both meters in the same period of time. That is, one observer held the watch and counted a whole number of revolutions of the disc of one meter while another observer counted revolutions (and a fraction) of the other disc in the same time interval as indicated by signal on the part of the first observer. On account of the fluctuations of the load, the results given by the integrating meters were considered the more reliable and were used in most cases in arriving at the final results, the indicating instruments being used for check purposes except in two instances.

The alternating power was measused by a polyphase integrating wattmeter and a polyphase indicating wattmeter connected to specially provided instrument transformers in the case of the Brooklyn tests. In Boston the same instruments were used, but in connection with the instrument transformers already installed.

The integrating meters on the direct-current side were of the astatic type and free from stray field errors. The indicating instruments were iron-clad, but the usual precautions were also taken to avoid stray field errors.

The capacity of each of the recording meters used was such that it was overloaded when the machine under test was only normally loaded, thus giving a higher degree of accuracy at the lower loads.

Standardizing of Instruments

The instrument transformers and the direct-current integrating wattmeters used in the Brooklyn tests were all carefully checked at the Electrical Testing Laboratories before the test. Particular attention was paid to the wattmeters, the checking being done with a potentiometer and standard resistances up to 5000 amperes. The errors due to change in temperature and to change in voltage were also determined.

The alternating-current wattmeters, both integrating and indicating, were checked at the Laboratories before and after the tests. The latter checks were made under the various conditions of voltage, frequency and power factor found in the tests. The same was done in the case of the direct-current millivoltmeter and shunt where checks were made at the various temperatures of shunt that had been noted in the tests.

The instrument transformers and the direct-current wattmeters used in the Boston tests were checked in position, as it was not possible to send them to the Laboratories.

Tests

Two, and in one case three, complete tests on as many different days were made on each equipment. Each test consisted in taking, in addition to no-load readings, five to six points on the efficiency curve, approximately as follows: 25-per cent., 50-per cent., 75-per cent., 100-per cent. and 125-per cent. load. At each load, not less than ten readings on the recording meters were taken, and each reading extended over a period of two minutes. The average indication of each of the indicating meters during each of these periods was also noted.

All of the synchronous-converter equipments were in one substation, hence, the character of the load, and the like, was the same for all machines. This was also true of the motor-generators.

The high-tension alternating power was measured near the point where the lines entered the step-down transformers (or motors, in the case of the motor-generators), and the direct-current power was measured at the buses. The results therefore include all losses between the high-tension alternating-current buses and the direct-current buses.

Data and Curves

Descriptive details of the equipments tested are given in Table I. The efficiencies are shown graphically in Figs. 14 to 19, inclusive. In Fig. 20 are shown curves which are averages of those obtained in the different tests on each equipment.

Results

On examining the results of these tests it will be noted that the different curves for each machine agree very well except those for converter "A." This may be accounted for by the fact that the brushes were old and hard, so that frequent sanding and oiling of the commutator were necessary. The effect of the latter operation was noticeable at once if readings were being taken at the time. Also, the curves for converter "A" are shorter than the others, because tests at the large loads could not be made on account of commutation troubles.

It will be noted that the two converters with inductive regulators have slightly different efficiencies, especially

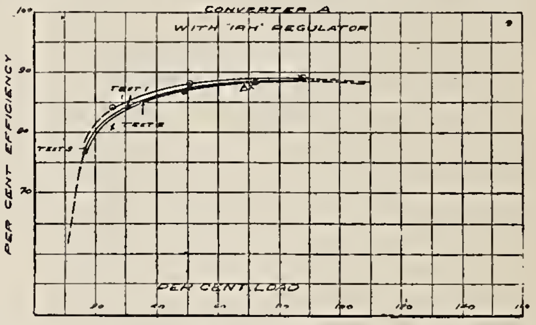


Fig. 14.—EFFICIENCY CURVES CONVERTER A

at light loads. This may be accounted for by the fact that converter "B" was built over two years before converter "A."

An examination of Fig. 20 leads to the following conclusions:

1. The prevailing opinion that synchronous converters with transformers are more efficient than motor-generators is corroborated. The extreme differences shown are about 6 to 7 per cent. at full load and 15 to 16 per cent. at 25-per cent. load.

2. The difference between the efficiencies of the various converter equipments is small, ranging from 3 to 4 per cent. at all loads.

3. The induction motor-generator is markedly superior to the synchronous type.

4. The difference in the shape of the various curves gives an opportunity for comparisons on a basis other than that of straight efficiency. It is evident that the shape of the efficiency curve is important as well as its position, and that it is desirable to have the maximum efficiency at a point where the machine operates the greater part of the time, which usually means at some load less than full load. The efficiencies at the lower loads should also be as high as possible.

All-Day Efficiencies

That efficiency in which the manager of a lighting and power company is most interested is the all-day efficiency or ratio of the total kilowatt-hours output to the total kilowatt-

TABLE I
DESCRIPTIVE DATA
CONVERTERS, 25 CYCLES

Test	Year of Instal.	Type	D. C Capacity, Kw	D. C. Volts	No. Poles	Speed, R.P.M.	Step-Down Transformers: No.	Capacity, Kw (Each)	H. T. Volts	L. T. Volts
A	1906	Ind. reg.*	1000	275	14	214	3	400	6300	170
B	1904	Ind. reg.*	1000	270	16	187.5	3	400	6450	170
C	1908	Split pole**	1000	270	10	300	3	400	6300	186
D	1907	Syn. boost.	1000	270	16	187.5	3	400	6450	170

All machines are six-phase. The transformers are cooled by air-blast and the secondary windings are double-delta connected.

MOTOR-GENERATORS, 60 CYCLES

Test Letter	Year of Instal.	Motor: Kind	Capacity, H. P.	A. C. Volts	No. Phases	No. Poles	Speed, R.P.M.	Generator: Capacity, Kw.	Volts	No. Poles	Speed, R.P.M.
E	1905	Ind.	1400	6600	3	24	300	1000	250	14	300
F	1906	Syn.	1400	6600	3	24	300	1000	250	14	300

*Made by different manufacturers. **Two-part pole type with compensating winding on main poles.

hours input for a period of 24 hours. As has already been pointed out, this depends on the shape of the efficiency curve as well as its position, and a machine may give a much higher all-day efficiency on one load curve than on another.

Fig. 21 shows three daily load curves. One is an actual curve, *C*,

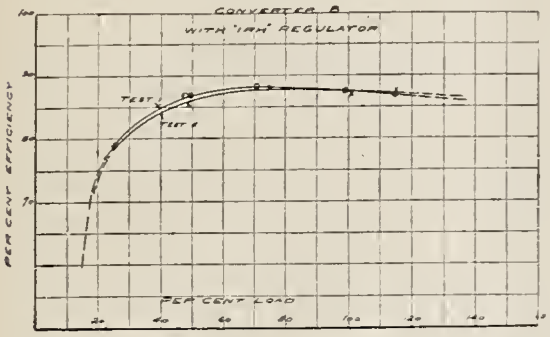


Fig. 15.—EFFICIENCY CURVES CONVERTER B

taken on a 1000-kw. machine operating in a substation of the Edison Electric Illuminating Company of Brooklyn. Two are plotted from assumed data, *A* being intended to apply to the exceptional case where the daily machine load factor is about 90 per cent. and *B* to the other extreme condition where the load is low most of the day but with a large lighting peak. Curve *C* may be considered an average case.

The curves show that from this standpoint the converters are as a class superior, since the curves reach a maximum more quickly. Of all of the curves, that for the synchronous booster type of converter equipment is the best, while the shape of those for

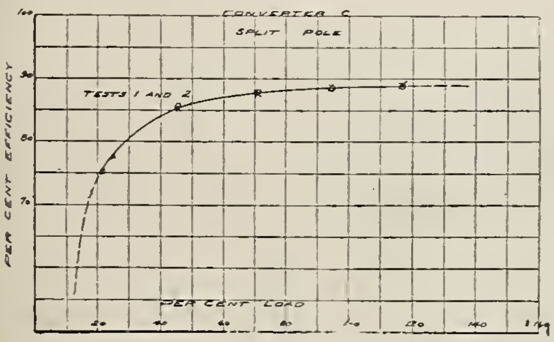


Fig. 16.—EFFICIENCY CURVES CONVERTER C

the split-pole converter and the induction motor-generator are the least desirable, because the low-load efficiency is low and maximum efficiency is at a considerable overload where the machines are rarely used.

All-day efficiencies have been calculated for each of the five types of conversion equipment on each of these three load curves. The figures are given in the following table:

The figures in this table show at once the effect of the shape of the efficiency curve. For instance, on the most favorable load curve, *A*, the equipment having the highest all-day efficiency is about 7 per cent. higher than the one having the lowest, while on curve *B* the corresponding difference is nearly 15 per cent. Furthermore, the equipments showing the least effect of changes in load curve are those having efficiency curves most

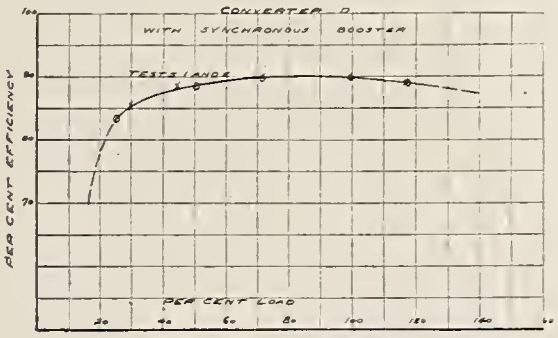


Fig. 17.—EFFICIENCY CURVES CONVERTER D

nearly horizontal. The all-day efficiency of the induction regulator converter (A) and the synchronous booster converter (D) changes 4 to 5 per cent. from the best to the worst load curve, while the all-day efficiency of the synchronous motor-generator changes about 13 per cent. under the same conditions.

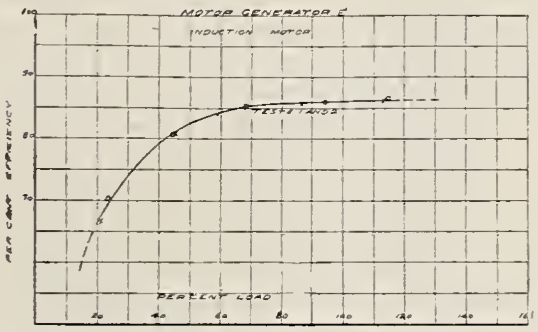


Fig. 18.—EFFICIENCY CURVES MOTOR-GENERATOR E

Distribution of the Losses

It would have been very interesting in connection with the efficiency tests to determine the distribution of the losses among the various parts of each equipment. The available time was entirely too short to admit of this being done, but estimates from manufacturers' specifications may be of interest.

In converter equipments the losses may be divided as follows: Step-down transformers, about 15 per cent; induction regulator or synchronous booster, about 40 to 50 per cent.; converter, about 3 to 40 per cent.; low-tension cable losses, about 5 per cent.

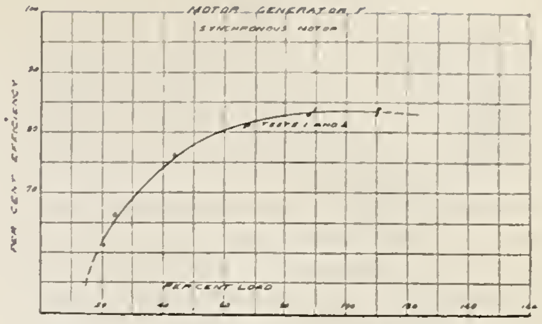


Fig. 19.—EFFICIENCY CURVES MOTOR-GENERATOR F

In motor-generators the losses are probably about equally divided between motor and generator.

NOTES ON OPERATION

It was not possible to make an extended investigation into the operating features of these various conversion equipments. The following notes were obtained from the engineers in charge of the particular machines on which the tests were made, and from the operators. They are therefore opinions based on experience:

Starting Methods and Time Required

The synchronous converters on the Brooklyn Edison system are all started from the direct-current side, and since storage battery current is always available in the substation, no other starting provision is made.

Five-step iron-grid starting rheostats are used, and provision is made for replacing a defective grid instantly with a duplicate by means of a throw-over switch. It might be noted that great care is taken to get the machine on the line without disturbance, and it is synchronized for zero volts by a low-reading voltmeter across the line switch, instead of a voltmeter on the line and incoming machine.

The Boston Edison Company has a standard practice of starting the motor-generators from the direct-current side, although provision is made for

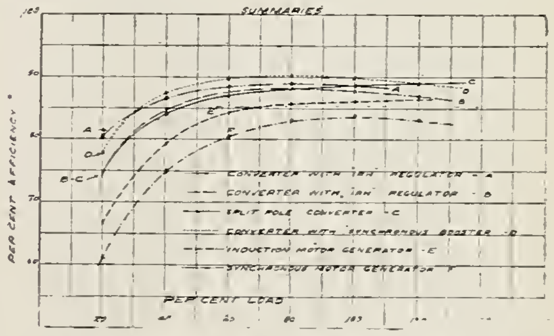


Fig. 20.—EFFICIENCY CURVES-SUMMARIES

starting both the induction and synchronous machines from the alternating-current side.

The time required to start and get into service was reported the same for all equipments, except one, at three to five minutes. The exception is the split-pole converter, which requires one to two minutes more because every change made in the field to ad-

ALL-DAY EFFICIENCIES

Equipment	All-Day Efficiency: Curve A, Factor 90.6	Curve B, Factor 31.2	Curve C, Factor 44.9
Synchronous converter, induction regulator (A)	88.6	84.7	86.9
Synchronous converter, induction regulator (B)	87.9	81.1	85.4
Synchronous converter, split-pole (C)	88.3	81.2	84.8
Synchronous converter, synchronous booster (D)	90.0	84.9	87.8
Induction motor-generator (E)	85.8	75.0	80.5
Synchronous motor-generator (F)	83.2	70.1	76.2

just the alternating electromotive force while synchronizing, affects the speed also. In case of emergency, other things being equal, preference would be given to the induction motor-generator over the synchronous motor-generator and the synchronous booster converter over the other two types of converters. It will be seen that, of the various starting synchronous apparatus, the direct-current method is used by both of these companies, as it means the least disturbance to line. Where direct current is not available, an alternating-current starting motor on the shaft (extended) would probably give the best results.

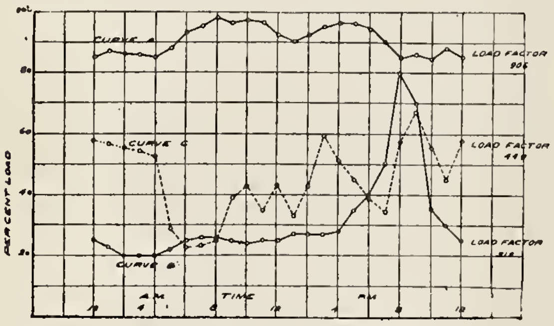


Fig. 21.—LOAD CURVES

Variation of Power Factor with Voltage and Load

In motor-generators the voltage and power factor are quite independent, but in synchronous converters a change in voltage at a given load produces more or less change in the power factor, hence more or less manipulation is required every time the voltage is changed. The curves in Fig. 22 show the extent of this change in power factor with change in voltage, load and main field current remaining constant. The regulator converter and the synchronous booster converter lower the power factor markedly at light loads with increase in voltage, but at 75 per cent. load and over the change is not appreciable. Of the three types of converters the power factor of the split-pole is least affected at any load. This is probably due to the fact that in this particular machine there are compensating windings on the main poles in series with the auxiliary pole so connected that the main pole flux is decreased or increased when the auxiliary pole is respectively increased or decreased. Thus the total flux is automatically kept practically constant.

Fig. 23 gives curves taken to show the variation of power factor with variation of load and with constant main field current. The power factor of the synchronous motor-generator is not appreciably affected at constant field current, therefore no curve is given. The induction motor-generator has of course a poor power-factor characteristic, but this can be compensated for, since in the Boston stations the other equipments are synchronous motor-generators.

Converters with induction regulators and synchronous boosters have a practically constant power factor at all loads with constant direct voltage. The split-pole converter shows a slight falling off in power factor with increase in load.

Operation Inverted

The motor-generators will operate equally well from either the direct or the alternating-current supply. In case of a short-circuit on the alternating-current end or sudden opening of the oil switches under load, the machines invert instantly without any trouble whatever. The same is true of the induction regulator and synchronous booster types of converter equipments; but with the split-pole converter, an inversion, in account of the sudden reversal in the field distortion, would be a very serious matter. The Brooklyn Edison Company is installing reverse current circuit-breakers on these machines, and their engineers consider that such a device should be considered a necessary part of a split-pole converter equipment.

Synchronizing and Hunting

All equipments synchronize about equally well, except the split-pole machine, which requires a little more care, as already stated.

No trouble from hunting has been experienced with any of the equipments. It should be considered, however, that the conditions are probably very favorable, *i. e.*, a large supply system at constant frequency and voltage.

Accessibility for Cleaning, Repairing, Etc.

The split-pole converter tested is the easiest machine to clean, because of the fewer poles and consequently more accessible armature. The induction regulator equipment means two pieces of apparatus, but one of them requires no more attention than the step-down transformers. Each motor-generator means, of course, two machines, each of which requires nearly as much attention as a converter. The synchronous booster converter, in the form where the booster is on the bed frame of the machine, has a serious defect in that the armature winding and leads are not accessible for cleaning except with compressed air. It is also more troublesome in case of repairs, as it would require considerably more time to dismantle.

Ability to Remain in Synchronism

The induction motor-generator will undoubtedly remain in synchronism under more severe conditions than any of the other equipments, but experience has shown that modern synchronous motors and synchronous converters do not fall out of step readily under sudden overloads or short-circuits. None of the machines on which the tests were made have ever dropped out of step due to such conditions.

Range of Direct Voltage

The range of direct voltage in the motor-gnerator is of course a maximum. The range in the converter equipments is largely a question of design, and in the machines tested the range is about the same, *viz.*, 100 to 125 volts. Inherently, the range is probably more limited in the split-pole type than in the booster or regulator types. The range of direct voltage is not of importance as far as normal operation is concerned, for the desired range under usual conditions is small —15 to 25 or 30 volts. But in the case of a complete shutdown and with the storage batteries low and falling rapidly, it is very important to have a wide range in the direct voltage in order to get the converters started and on the line.

Overload Capacity

The overload capacity of these various equipments is largely a question of design and rating. Inherently, it

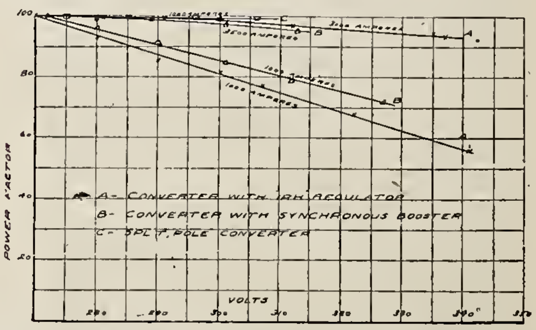


Fig. 22.—CURVES SHOWING VARIATION OF POWER FACTOR WITH VOLTAGE

is probable that the induction motor-generator will carry a much larger load than the synchronous motor-generator, on account of the greater tendency of the latter to fall out of step. The induction regulator and synchronous booster types of converters will carry more load than the split-pole type (two-part) on account of the sensitive commutation in the latter.

Cost

It was found that the cost of each of the particular equipments dealt with in this paper depended on and was influenced by so many other considerations that no comparison of value could be made. Comparative prices are in general of doubtful value, since they are not necessarily a true measure of the cost. The purchasing price is usually largely influenced by other factors, such as competition,

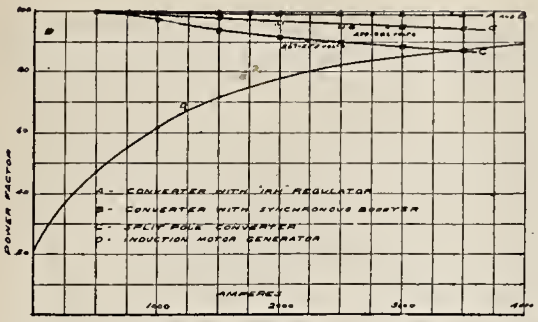


Fig. 23.—CURVES SHOWING VARIATION OF POWER FACTOR WITH LOAD

size of the order, relations between buyer and seller, and the like. Data that have been published give varying costs per kilowatt for the same class of apparatus, but the general indication is that synchronous converters with the step-down transformers and regulating auxiliary cost very little less than motor-generators, probably only 5 to 10 per cent.* As to the relative cost of the converters, it is understood that the cost of the three converter equipments referred to herein is practically the same.

*H. G. Stott, *Proceedings* Association of Edison Illuminating Companies, 1900; W. C. L. Elgin, *Transactions* International Electrical Congress, St. Louis, 1904.

Floor Space

The floor space occupied by the various equipments is indicated in the following table:

Equipment		Total Space, Square Feet	Kilowatts per Square Foot
Converter induction, regulator type	(A)*	222	4.50
Converter induction, regular type	(B)*	244	4.10
Converter, split-pole type	(C)*	182	5.50
Converter, synchronous booster type	(D)*	158	6.32
Induction motor-generator	(E)	192	5.22
Synchronous motor-generator	(F)	192	5.22

*Blowers and ducts so arranged that no additional space is required.

GENERAL CONCLUSIONS

The answer to the problem "motor-generators *vs.* synchronous converters" for lighting and power work depends to a great extent on the circumstances in each individual case. In general, however, the data given in this paper do not justify the use of motor-converters except possibly on 60 cycles or where the alternating supply fluctuates badly. The principal advantage of the motor-generator is its flexibility and the entire independence of the direct-current system from the alternating system. If the high-tension alternating-current supply is reasonably free from fluctuations, these advantages are of no value and are more than counterbalanced by lower efficiency and increased first cost.

Comparisons of the various types of synchronous converters are at the present time in favor of the synchronous booster converter, but the split-pole machine is so recent a development that improvements in design, which will undoubtedly be made, may improve the efficiency curve and the operation of the machine to such an extent that this conclusion may be reversed.

Factors that should be considered in making street lighting contracts

By SAMUEL RUST

Greenville Electric Light and Power Company, Greenville, Ohio

There are 143 private corporations in Ohio engaged in the business of furnishing electricity to the public, and of this number more than three-fourths are dependent upon the street lighting of their respective municipalities for their financial success. In almost every other line of business, when the success or failure of the entire concern depended upon the business of one customer, the factors which enter into that business would be well known to both parties and a basis arrived at which would be satisfactory to all concerned in the contract. But in making street-lighting contracts with municipalities, the game so far has been a catch-as-you-can affair with one side at least generally ignorant of what they were doing and suspicious of the other because they were ignorant and because they were of necessity compelled to deal with a monopoly.*

I think it will be agreed by all present that if this part of the lighting business was understood by the municipalities as well as by the companies making the contracts, there would be better prices and more satisfactory contracts made.

*O. E. L. A., 1909.

It is not the intention of this paper to set out just what the prices for street lighting should be, as prices must vary with different localities and is dependent upon the amount of lighting, cost of fuel, cost of equipment and labor, kind of lights, lengths of contracts, etc., but there are some factors which enter into this branch of the lighting business which each party to the contract should know of and for which they should make due allowance in making such agreement. These factors I group into the following heads:

Length of contract, kind and number of lights, changes in position of lamps, outages, schedule burned, time of payment, costs of service and manner of contracting.

The length of time that a street-lighting contract should run is a very essential factor to be considered by both parties to the bargain. The statues of Ohio have fixed the maximum at ten years. The question is, should contracts be for any less period. If the company is a progressive one and keeps abreast of the times in adopting new improvements for their street-lighting service, it should most assuredly not be less, as every such company can count upon completely changing its street-lighting equipment at least once in every ten years, and this calls for an outlay that shorter-time contracts will not justify. Every street-lighting contract should provide that the company furnishing the lights should have the right to change their system to a newer or better system of equal or better intensity during the life of the contract, subject to the approval of the Council or Board making the contract. Instead of this provision injuring the municipality, it would benefit it by giving it the benefit of the improvements in electrical service which are appearing quite frequently, and it would be an incentive to the company to furnish the city with the best and up-to-date service.

The proper method of dealing with outages is probably yet to be found. To compel the company to stand the exact price of the lamp when it is extinguished and should be burning is unfair to the company because of the equipment cost and fixed expenses which always exist, while to excuse the company for continued outage would likewise be unfair to the muni-

cipality. A good plan is to agree in the contract just what the outage should be per hour per lamp, and it is suggested that the amount be two-thirds of the price received for the lighting of the lamp.

The kind of lamps to be used in lighting a town or city must depend somewhat upon the size of the municipality. Companies should be careful not to overlight a city in the beginning; as all municipalities grow rapidly, and there is a constant increase in the number of lights wanted, the lighting bill may become too great in comparison to other city expenditures and produce dissatisfaction. While most municipalities do not make any mistake in this regard, and are generally underlighted, there are some that have more lights than the city can well afford to pay for. This is like overselling a man in goods. He may pay for the goods, but always results in a dissatisfied customer. So far there has been nothing invented for street lighting superior to the arc lamp. Its reliability invention of its rays and ease of arranging its circuits had made it a favorite in any contract for street lights. In view of the recent inventions of the series tungstens, a price should always be agreed to for the installation of smaller units in out-of-the-way places in order that the city may light dark spots at a less cost than the arc lamp, which is too large for the purpose. Series tungsten are now made to fit the amperage of almost every size arc lamp, and can be installed on the same circuit and operated simultaneously with the arc lamps. Reports from this class of lighting are all favorable as to its satisfactory operation and length of life. In the smaller municipalities it is a question whether the series tungsten will not in time supplant arc lighting entirely. Its economy of consumption and consequently lower price will enable the introduction of a largely increased number and avoid the shadows of foliage which is always dense in the smaller towns.

The number of lights that a municipality can use will determine in some measure the price that should be paid. At the end of this paper will be found an estimate of the cost of operating a 100-lamp street-lighting outfit, and it may be safely said that if the number is decreased the cost is increased, and, further, that the price for a street lamp should not be fixed without taking into consideration the fact that the fixed expenses of the plant, sometimes called overhead expenses, will be the same whether 50 or 100 is contracted for.

The schedule that lamps are to be burned must also depend upon the size of the municipality. The writer is inclined to think that it is a mistake to furnish all-night and every-night service in towns of less than 5000 inhabitants; for such towns a moon-light schedule is preferable; but every contract should provide that in case the nights are cloudy or stormy, that the lights should be burned during such conditions. Where the town is above 5000 and under 10,000 inhabitants, it is a very good plan to have the contract provide for four nights off in each month, unless they are stormy or cloudy. By doing this the plant is enabled to make repairs to its arc-lighting equipment without sustaining outages, and plants in cities of this size cannot afford to have so large an equipment as will guarantee continuous service. Cities that are above 10,000 will usually require all-night and every-night service, and cities of this class will usually justify a sufficiently extensive electrical equipment that will enable the company to give every-day service on its street-lighting service without inconvenience.

The time at which bills should be paid should always be stated in the contract. It is preferable to make it monthly. To allow bills to grow too large causes the public to murmur at their size, and, in addition, it is just as easy for the city to appropriate in its semi-annual appropriation as it is to allow bills to run on and be paid quarterly or semi-annually, besides it is a great convenience to the company to have the use of the money, as the sum usually received for street-lighting is sufficient to take care of the operating costs in a considerable measure.

The costs which enter into street lighting should receive very careful consideration from the company. The writer is of the opinion that many street-lighting contracts are made below actual cost. The following figures are based upon the average cost of a small plant of 100 arc light capacity, taking into consideration cost of construction, maintenance and operation and using the standard enclosed arc system:

I estimate that each lamp will consume 600 watts per hour, and the time of burning 4000 hours per year; this will make a total consumption of 2400 kw-hr., or 3.217 h.p.-hr. per lamp per year. Estimating that the average small plant will require 6 lb. of coal per horse-power (the coal consumption for each lamp would be 9.65 tons, which, figured at $2.50 per ton in front of the boilers, would be $24.12. The lamp will have to be trimmed about 50 times, and I estimate the cost of trimming at $1.00. It will consume 50 pairs of carbons, which I figure at $2.30. The repairing time and material would amount to $5.00, cost of installing about $120.00 per lamp, and figuring 10 per cent. depreciation, would amount to $12.00 per year. Cost of labor and salaries would aggregate $12.00 additional, and the interest upon the investment $7.20, or a total cost of $63.62 per year. That these figures are certainly low, I would refer to the report of the commission appointed for St. Louis to investigate the advisability of that city providing its own street-lighting system, in which they found that the cost of operating an arc lamp for a city the size of St. Louis would be approximately near $70.00 per annum.

The writer is inclined to think that the time has arrived to educate the people on the costs of producing electricity, and instead of dealing with a municipality as if you were handling something that was mysterious, the factors which enter into such contract should be known and understood by all parties thereto. When it comes, the prices for street lighting will be more equitable and will not be lower than they are now.

Westinghouse Type C Three-Phase Transformers

Recent marked improvements have been made in Westinghouse type C three-phase transformers, resulting, besides the advantages already enumerated as inherent to this design, in decided advances in both construction and performance. In these transformers the losses are reduced below those of any ordinary equivalent combination for transforming three-phase power, while experience in design and modern factory methods have produced a highly serviceable apparatus that can be sold below the price of the equivalent single-phase transformer group.

These type C three-phase transformers are made in sizes ranging from 5 to 75 kw. capacity, and display very high efficiency at all loads, as well as close regulation when operating on currents having low power-factors.

The three high-tension leads enter from the front side of the transformer, the low-tension secondaries issuing from the pole side of the case. Provision has also been made for bringing out neutral leads, when desired, from both the high and low-tension windings. Separate terminal blocks are provided for both the high and low-tension leads of each of the three phases. Each low-tension winding comprises two coils which can be connected in parallel for 110 volts, or in series for 220 volts, the standard designs being for 2200 volts on the high-tension side.

Relation of Electric Vehicles to Central Station Business

By JAMES T. HUTCHINGS

It has been generally conceded that the best-paying load for the central station is that which gives the best load factor, and that the best-paying electric properties are those having the highest yearly load factor. A central station manager, however, finds it next to impossible to change the general habits of his community. Our load charts all show that there is very little demand for current from 11 o'clock at night to 7 o'clock in the morning.*

The electrical vehicle will generally be used only during the day and evening, and can advantageously be charged in from six to eight hours. This introduces a class of business which, by suitable preferential rates, will use electric current at just the time we are all anxious to sell it. This condition permits of a great improvement in the daily load factor, and the records from the ledger footing show that it also increases the yearly load factor, due to the fact that vehicles are used for pleasure more in the summer than in the winter.

Our sales of electric current for charging storage batteries for vehicles have increased from 285,470 kw-hr. in 1906 to 495,490 kw-hr. in 1908, or by 73 per cent., and our income for the corresponding year from $12,458.91 to $19,796.56, or by 59 per cent.

Analyzing our ledger footings still further, we find that in December, 1906, we were supplying 98 private charging stations, which consumed during the year 111,557 kw-hr., and gave us an income of $5,881.80, or 5.28 per cent. per kw-hr.; while in December, 1908, we were supplying 140 private stations, which used during the year 194,171 kw-hr., giving us an income of $10,730.63, or 5.51 cents per kw-hr.

In December, 1906, we were furnishing current to eight public charging stations, which used during the year 173,923 kw-hr., giving us an income of $6,577.03, or 3.78 cents per kw-hr.; while in December, 1908, we were supplying 14 public stations, which used during the year 301,279 kw-hr., giving us an income of $9,065.93, or 3 cents per kw-hr.

The above figures show that our income from the private charging stations has increased 82 per cent. in two years, against an increase of 38 per cent. for public charging stations. While to produce this increase of 82 per cent. in income for private stations we furnished only 74 per cent. additional current, on the other hand, for the public stations we were obliged to furnish 73 per cent. increase in current for an increase of only 38 per cent. in income. The motive in making the lower price per kilowatt-hour for public charging stations was the desire to eliminate competition from isolated plants and to encourage the use of current between the hours of 9.30 A. M. and 6.30 P. M.

It being granted that at a fair rate the sale of current for the charging of batteries for vehicles is desirable and profitable business, the question arises —what attitude should the central station take to encourage this business? The first thing that comes to mind is the granting of special low rates for the current used. This has undoubtedly assisted many companies to create a considerable business in this line. From our own experience, however, we have found that a low rate is not the greatest incentive to an increase in business.

As the batteries have previously been handled by our consumers, the electric vehicle owner has been using too much electricity and has paid the company too much money therefor, the larger part of the current having been used to the detriment of his storage battery. A low rate for current induces carelessness on the part of the customer as to the manner of use.

We find that what we most need is a campaign of education, which shall increase the customer's knowledge of the proper methods to be pursued in charging his battery and handling his vehicle, bringing home to the consumer the fact that if the vehicle in operation uses twice the amount of current that it should to do a certain amount of work, owing to friction, bad alignment, and the like, the work actually done has decreased by more than 50 per cent., and the life of the battery by more than that amount.

Our company has for some time appreciated the value of these features and some of the difficulties that the vehicle owner labors under in getting satisfactory service out of the electric vehicle. For this reason we organized on the first of March of this year a department to give this matter special attention, and have placed in charge thereof a competent engineer of wide experience in the handling and maintaining of batteries. Investigation by this department thus far has shown conditions to be even worse than we had anticipated.

While our electric vehicle department has been in operation for only a very short time, I wish to state a few of the important things that have been accomplished.

The department found that the principal carting and trucking firm in our city had two electric trucks, which had not been in operation for eight months. These trucks, properly operated, should give us an income of from 50 to 60 dollars a month. The owners stated that the only reason the trucks were not operated was the excessive cost of maintenance and their unsatisfactory performance.

In order to place these trucks again in commission the department made this proposition to the owners: That we would fit up the two trucks in A-1 condition, and that if, at the end of 60 days' trial, the owners were not satisfied with their operation, there would be no charge for the repairs. If, however, the trucks were made satisfactory, we would charge the owners for only the actual material used, making them a present of the labor and current used in putting the equipment in first-class condition.

The two vehicles were put on the street and have been in operation for two months, with the result that the customer has paid us $1000 for the material used and is seriously considering the purchasing of additional electric trucks. The superintendent of our electrical vehicle department gave this installation his particular attention, and after the vehicles were placed in commission gave personal supervision to the charging of the battery. On comparing notes he found that whereas under his supervision it was necessary to give the battery only 40 ampere-hours charge on a particular day, under the former operation and for the same conditions of running a charge of 180 ampere-hours had been used, 140 of which had been wasted and had served only to decrease the life of the battery through the softening of the plates.

To cite another instance: A woman owning a runabout had taken this machine to a number of different garages for repairs, and in each case it had been brought back in worse condition than before. She was absolutely dis-

*N. E. L. A., 1909.

gusted with the entire proposition, and we learned that she was negotiating for a gasolene runabout. Our superintendent saw this woman personally, and she stated that if the runabout could be made to run 15 miles satisfactorily on one charge she would be very glad to pay any reasonable amount for the repairs, but that if he found that he could not do this, she would be glad to make him a present of the vehicle to get it out of her sight. A careful inspection of the outfit showed that the controller had shifted in such a manner that whenever it was used the battery was practically short-circuited, also the battery was found to be badly sulphated. The vehicle was brought to our shop, the controller repaired, and the battery re-formed. Our superintendent then took the owner for a drive of 25 miles, and she was so pleased with the operation of the vehicle that she requested the privilege of sending all of her friends who owned electrics to our repair shop.

The writer does not wish to give the impression that it is the general practice of our garages and repair shops in Rochester to do poor work. We have in our city, I believe, as good men doing this work as in any city of corresponding size, but the trouble is that the repair shop is not sufficiently interested in the successful continuous operation of the electric vehicle, looking only to the immediate returns for the individual repairs and the profit of a single job.

It is this careful attention to minute details that makes the success of the electric vehicle possible, and if these details are followed up there is no competitor to the electric vehicle in its own proper field.

My advice to the central station manager would be that he take the electric vehicle situation seriously and give it the same attention he has given the sale of electric power, outline and display lighting, and heating appliances. If he does so he will find the electric vehicle a better medium for the sale of his product than any that has previously been brought to his attention.

Tests of Moore Tube Lighting Installation, New York Post Office

By E. P. HYDE and J. E. WOODWELL

SCOPE OF TESTS.

The tests were divided into four general heads, as follows:

1. Illumination measurements at various stations to determine quantity and uniformity.
2. Measurement of energy and power factor.
3. Determination of flux of light.
4. Stroboscopic determination of variation in illumination throughout a cycle.

(1) ILLUMINATION

The illumination was measured by means of a Sharp-Millar illuminometer, made by Foote, Pierson & Co., and previously calibrated at the Bureau of Standards. This calibration showed the scale of the instrument to be in error over a range from 18 foot-candles to 1.5 foot-candles by approximately 9.5 per cent. By a preliminary test the voltage of the small comparison lamp, furnished with the instrument, at which it matched the Moore tubes in color, was determined. The instrument was then calibrated with the comparison lamp at this voltage, both as an illuminometer and as a photometer. The milk glass screen was tested when light was incident at various angles, and found to vary from the cosine law by as much as 20 per cent. at 75° incidence. A plot was made showing this error for different angles of incidence. Plots were also made giving the actual foot-candles for any scale reading when the instrument is used as an illuminometer, and the actual candle-power when the instrument is used as a photometer.*

The illumination was determined on a plane 36 in. from the floor.

For the first series of readings the reflectors over the tubes were removed. For the second series they were in place. The reflectors used were corrugated mirror reflectors.

The results given in the following table are expressed in terms of the unit of candle-power maintained at the Bureau of Standards prior to July 1st of the present year.

TABLE I—ILLUMINATION IN FOOT-CANDLES.

Stations	Series No. 1 without reflectors		Series No. 2 with reflectors	No. 2 less No. 1 in per cent.
1	2.4		2.5	4
2	6.2		6.9	10
3	7.8		8.3	6
4	7.9		8.6	8
5	5.0		5.2	4
5	5.0	Tubes in room D out		
6	2.5		2.6	4
7	5.9		6.2	5
8	8.6		9.1	5
9	9.0		10.0	10
10	7.3		7.4	1
11	3.7		3.7	0
12	3.4		3.4	0
13	7.8		8.7	10
14	8.8	36″ Reference plane from floor	10.0	12
14	9.6	48″ " " " "	10.4	8
14	10.3	60″ " " " "	10.5	2

(2) ENERGY.

During the illumination measurements energy readings were made on tube B in series 1, and tube A in series 2.

The results are given in Table 2.

TABLE II—AVERAGE ENERGY CONSUMED DURING SERIES 1 AND SERIES 2.

	Volts	Amperes	Apparent kilowatts	Actual kilowatts	Power factor Per cent.
Series 1—Tube B	210	18.8	3.95	2.50	63
Series 2—Tube A	213	15.4	3.28	2.27	69

The floor area illuminated by tubes A and B approximates 1675 sq. ft., so that the watts per square foot are 2.85.

(3) FLUX.

For the purpose of determining the flux, a space was screened off enclosing about fifteen feet of tube B. This screening was accomplished by erecting four uprights at the corner of a 15-ft. square and wrapping around them heavy felt cloth, forming a room from which practically all extraneous light was excluded. A brass piece with an opening exactly 1 ft. long was made to fit the tube, and when set in place, the remainder of the tube within the enclosure was wrapped with felt, so that the only light within the enclosure came from the 1-ft. length of the tube. A semi-circular disc was made with a piece exactly fitting this 1-ft. opening. This disc was provided with an adjustable rod swinging about the centre of the edge of the disc nearest the tube. The other end of

*I. E. S., 1909

the rod was provided with a small flat disc whose plane was perpendicular to the axis of the rod.

The illuminometer was changed during the test so as to serve as a photometer, by removing the milk glass screen and replacing the mirror at the elbow of the diffusing screen. The first measurement was made with the photometer directly under the opening, so that the photometric axis made an angle of 90° with the axis of the tube. This was called the 0 angle. The distance used was approximately 4 feet. The photometer was then moved, raised and adjusted by means of the rod and disc until its axis made an angle of 20° with that of the tube.

Readings were taken at the angles 0°, 20°, 40°, 60°. At 60° the readings were repeated as a check, and at 0° an additional observation was made at a longer distance. The results are expressed in apparent candle-power, which in this case means the candle-power which a point source placed at the centre of the tube must have in order to produce, at the given distance, the illumination measured.

TABLE III—FLUX TEST.

Angle degrees	Distance in feet	Apparent candle-power
0	4.43	9.4
20	4.48	9.4
40	4.45	9.1
60	4.50	8.3
60	4.50	8.3
0	4.43	9.4
0	10.48	9.2

It is evident that when the photometric axis is normal to that of the tube, light will fall on the photometer screen at different angles of incidence, depending upon the distance of the screen from the tube and the distance of the different light-giving portions of the tube from the intersections of the photometric axis and the tube axis. It was found by analysis that the decreased illumination produced by these effects was compensated for by the fact that the light received on the screen does not come from the cylinder 1 ft. in length, but from a cylinder of wedge shape whose front elements are 1 ft. in length, but whose rear elements are considerably longer. It was found, therefore, that to a very good degree of approximation, probably well within the errors of reading, the mean spherical candle-power could be computed from the results obtained, assuming the candle-power to be that of a point source located at the center of the tube. This mean spherical candle-power was found to be 9.0. From this we get the total flux from 1-ft. length of the tube to be 113.1 lumens. Since the total length of the tube B is 2 by 56 ft. 7in. (see Fig. 1), or 113.17 ft., we have as the total flux from tube B, 113.17 by 113.1=13,000 lumens. Assuming the power to be 2500 watts (see Table 2), we have as the efficiency 5.21 lumens per watt. The mean spherical candle-power of the tube as a whole may be taken as the lumens divided by 4π, or 1034.

The watts per mean spherical candle for tube B will then be 2.42. Assuming the same value for tube A, the spherical candle-power per square foot of the area illuminated by tubes A and B will be 1.18.

(4) STROBOSCOPIC TEST.

Owing to the fact that when a tube is running on single phase there is a succession of images of any moving object instead of a continuous image, a stroboscopic test was made to determine the fluctuation in illumination and to see if a remedy could be found by using two phases, 90° apart.

The stroboscope used was made by attaching to a small induction motor a disc having a small sector opening in it. The motor was mounted on an arm which turned about a vertical axis passing through the axle of the motor. The speed was adjusted so as to give four maxima and four minima per turn. In this way it was not necessary to turn the instrument through more than 180° in order to pass from a maximum through a minimum. This procedure was necessary because the tube of the illuminometer prevented a complete rotation of the arm holding the motor.

The stroboscope was first set up half way between the tubes A and B, and at a height approximately six feet from the floor. When both tubes were running on the same single-phase current, the range between the maximum and minimum was from 0.096 foot-candle to less than 0.012 foot-candle, or at a ratio of 8 to 1. Owing to the finite size of the opening in the stroboscope disc, and the finite size of the screen of the illuminometer, it is impossible to get a zero illumination when the current is at the zero point of the wave cycle.

The two tubes were then put on separate phase, 90° apart. In this case one of the circuits was a power circuit involving the possibility of fluctuations in the line voltage. The range was then from 0.16 to 0.08 foot-candle, or a ratio of 2 to 1, as compared with a ratio of 8 to 1 on single phase.

It is evident from the results of this test that the objectionable flicker noticed in moving objects, when both are on the same phase, can be largely cut down by running the tube on two phases 90° apart.

Ives kindly consented to make a new set of measurements on the tube in the New York Post Office and to present this data, together with that of other tests made by him on Moore tubes. Unfortunately, the original tube on which the previous measurements were made has since been operated as a nitrogen tube rather than a carbon dioxide tube. It has been necessary, therefore, as will no doubt be explained by Dr. Ives, to change over again the tubes from nitrogen to carbon dioxide.

Recent Developments in Secondary Distribution Work

W. H. VANDERPOEL

It is intended in this paper to present a few short descriptions of relatively new practices which have more particularly affected the problems of secondary distribution. Quite often these special installations are only suited to peculiar conditions, and when attempted elsewhere, unforeseen local obstacles arise which prohibit their application. Besides reference to such innovations, mention is also made of the general trend toward improvements in outside plant details and the adoption of certain equipment; all of which bear pertinently on secondary distribution. Many of the remarks are not descriptive of new work, but while the features referred to may be well known, it is evident to those who are watching the progress of secondary construction that many small, though not unimportant, improvements have not yet been generally employed.*

SECONDARY LINES.

Many recommendations covering the construction and operation of lines in general are also applicable to secondary mains. The natural location for secondary wires is on the lower

*N. E. L. A., 1909

arms, preferably the lowest arm. Where most of the overhead services are being taken off to one side of the street, it is well to have the wires on the outer pins at that side; but where the mains quite equally supply both sides, they are better located toward the center of the arm. Long sections and staggering lines are always objectionable, but extremely so in towns or cities. Even at additional cost in securing through right of way the poles should be made to run as continuously as possible on one side of the street. As a rule, poles can not be guyed in city streets, therefore the resulting side strains at the crossing points soon pull them out of line, and also cause much pin breakage. The poles will, in the course of time, press out the curbing, which often leads to bitter complaints from property-owners.

Where there are many trees, some skill is required to lay out lines so that a minimum interference is obtained. If the trees have grown to a good height it is often feasible to have the construction low enough to go under the branches. If the trees are of the varieties that do not attain great height it is in many cases practicable to entirely clear them with higher construction. Where the primary or series circuits are in the foliage it is customary to use both tree wire and molding; the former to prevent destructive effects to the tree, and the latter to withstand the chafing action caused by the swaying of the boughs. Thoughtful attention will often show the way to bring in the primaries to transformers from intersecting streets with comparatively little obstruction, and the worst spots can, with a little ingenuity, be avoided by the higher potential wires. Many primary sections through these objectionable places could be done away with by more careful selection of transformer sites; approaching the transformers where there are clear runs, and then banking them to a secondary 'bus which could pass through the trees without difficulty.

A good cross-arm arrangement for secondary wires is to always place them on adjacent pins, with the neutral in the center if there are three wires. Putting primary wires on the same arm as secondaries seems like an invitation to trouble. If so placed it would appear that the only acceptable positions would be where the two voltages were separated by the pole; though even that might not always prevent their swinging together on long spans. After locating the wires properly the next thing is to have them run continuously in corresponding positions, and where taps are made they should be direct and clean so that the eye can easily trace the connections. Pole wiring deserves close study. Wire bends should be nicely angled, the wires straight and never hung loosely, as a wild medley of lines and taps may cause trouble, and at least can only have a prejudicial effect on the public. Such pole fixtures as shown in Fig. 1 are doubtless familiar to many. Their use

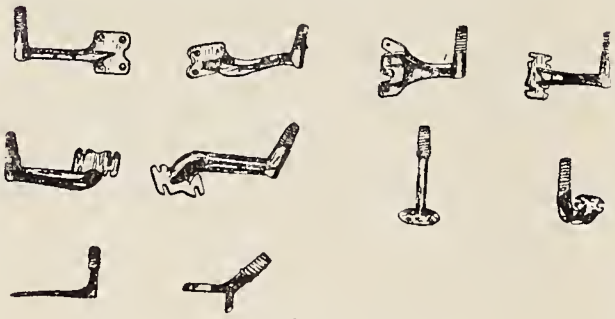


Fig. 1

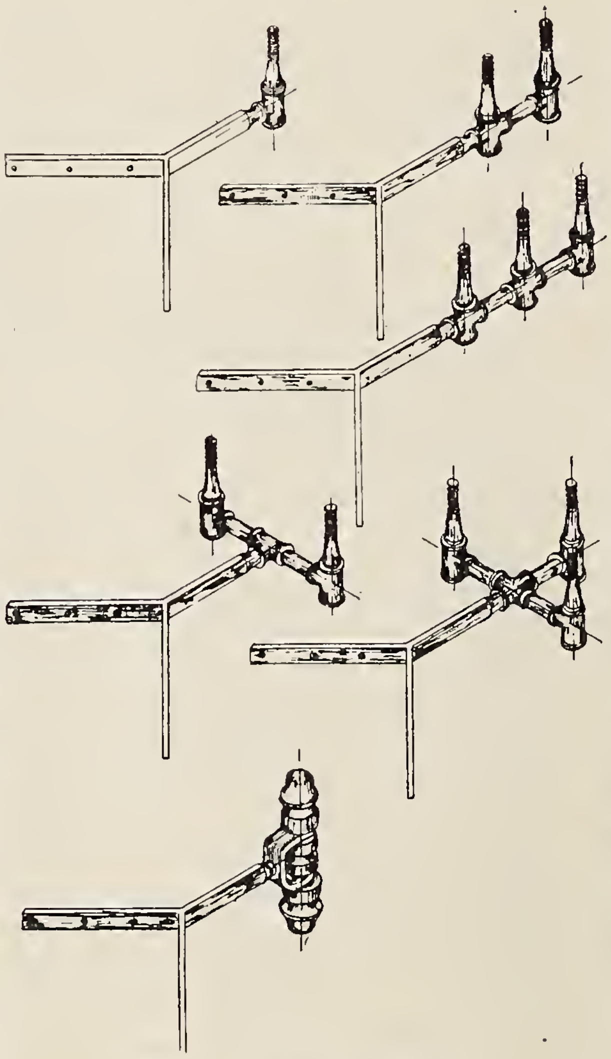


Fig. 2—CORNER BRACKETS

leads to considerable economy and excellent results in pole wiring. Where branch lines carry but two wires, spreader brackets can be used to good advantage, thereby dispensing with unnecessary "buck" or reverse arms.

CUSTOMERS' SERVICES

In the overhead system the entrance wires, or service, will be considered that portion which extends from the pole secondary mains to the outlet taps on the building to be supplied. In the underground system it will be the extension from the secondary mains in the manhole to the customer's service box, which is generally located in the cellar or basement of the building to be supplied.

A crude form of overhead service connection often seen is where the service wires, kinky and crooked, are tapped directly to the line wires, then dropping from these taps make a haphazard attachment to the intended building, running clumsily to the outlets on unsightly wooden brackets or pins. A neat and secure method of effecting the same connection could be accomplished by using service cable fastened at the pole end to spreader brackets, the taps to the mains being made back of the strain, and the cable then stretched to a suitable point of suspension on the building. The cable should take the most straightforward path to the outlets, being securely supported at proper intervals by galvanized or painted brackets.

If the service is extremely long, or the conductors extra heavy, it is necessary to use single wires, owing to the excessive weight which would be imposed on the fixtures by the cable. In this event only unkinked wire should be used and everything done to make the whole job as attractive and stable as possible. Very often the use of cable will overcome a prospective customer's objection to the unsightliness of many wires on his building. If the wires drop nearly straight from the lowest cross-arm, it might do no harm to dispense with the pole brackets, making the taps directly to the mains; but the connection would not be as unquestionably reliable.

Fig. 2 shows some types of the metal fixtures referred to. They come in various shapes, so they may be easily adapted to different structural conditions. Galvanized or painted fixtures are more durable, look better, and do not stain the building sides with rust as do the black iron fixtures. Figs. 2 and 3 show some flanged types made and used by one company. This company favors making them at home, as they can be turned out in any desired design at moderate cost.

The conditions back of each case govern the class of construction, and pecuniary reasons may particularly affect the choice of material; but security and continuity of service should rank before cheapness even in the smallest of plants. It is not contended, for instance, that the use of rubber service cable, or galvanized fixtures, is imperative to safe construction or certainty of operation, though some managements appreciate the advertising value of such niceties, and strain a point to make the investment.

The trend in subway work is likewise toward improvement in details, and in growing cities due foresight is paid to the largeness of things; more

capacious manholes, to avoid an awkward mess of cables, transformers, boxes, and the like; properly shaped and drained manholes; ampleness in

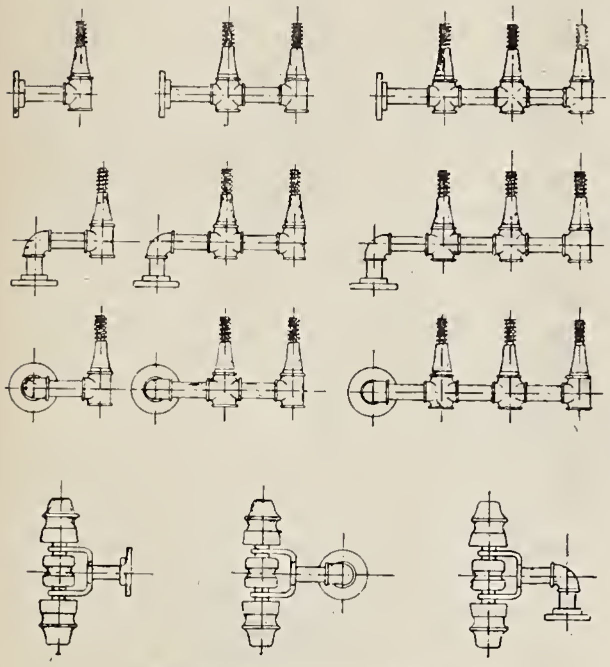


Fig. 3—BUILDING BRACKETS

duct capacity, with plenty of size to duct and pipe; abundant capacity in service copper; methodical separation of primary and secondary cables, discriminate location and direction of conduit pipes; frequent inspection and better care of manholes; careful tagging of cables; sufficient insulation and protection of cables in manholes, and so on with an infinite number of things that have only been worked out after years of patient evolution. Too much stress can not be laid on

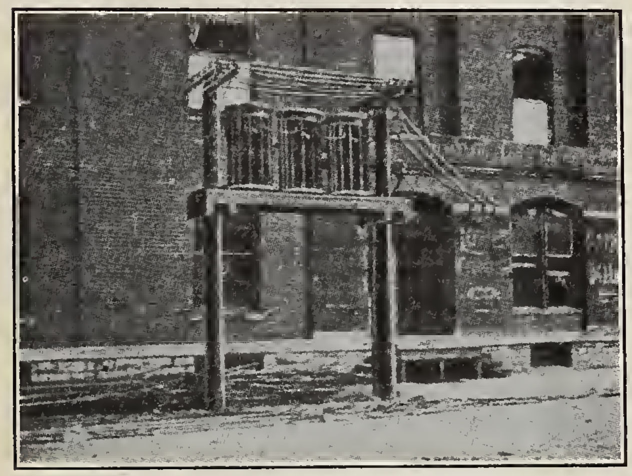


Fig. 4—PLATFORM TYPE OF TRANSFORMER SUPPORT

the necessity of looking beyond the moment, of installing equipment, particularly copper, with enough margin to anticipate imminent growth. Wasteful investment is of course not advocated, but it is well to take advantage of the dire experience of installations that were stinted in such things.

A common method of cutting in subway services is to tap the service cable to the secondary mains in the nearest distribution manhole, running the cable through pipe into the basement to the service box. Some companies prefer asphaltum-treated service pipe, others use galvanized, though opinions differ whether there are sufficient benefits to offset the extra cost. Where an underground service is led down a pole, a neat pipe job can be made by capping the pipe with a weatherproof condulet. These condulets come in standard sizes, are reasonable in price, are interchangeable, and certainly look better than the crude caps and puttied pipe tops so frequently seen.

Although armored cable has been used for many years in connection with Edison tube systems, other applications have recently been found. An outside wrapping of jute covers the steel-tape armor which is designed to protect the cable proper from mechanical injury. This cable has the inherent disadvantages of any buried conductor system, but it is found helpful in places where a more flexible connection than regular forms of conduit is required; for example, for long and tortuous house services, for park or suburban street lamp laterals, and similar fields. Its cost is moderate, it is durable, and, all in all, it seems a highly useful commodity whose total merits may not be wholly known.

TRANSFORMERS

It would be most difficult to prescribe any general method for distributing transformer capacity to suit all conditions. The circumstances in each case will dictate the course, though it is possible to distribute such capacity so that a material saving either in copper or transformers will be brought about. It is now more generally realized that the grouping of customers on a single transformer, or on secondary systems supplied by a number of large transformers banked together, will in the end net a considerable economy. One territory having mixed loads on three-wire mains, with the power load constituting about 30 per cent. of the whole, averages a total installed transformer capacity of approximately 50 per cent. of the total connected load. This subject, however, is so broad that no more than a general reference to it can be made in this paper. Many different classes of consumers will be found in one place, while another may have only two or three distinct groups to provide for. Policies differ in the matter of overloading transformers, and where one locality averages, say, 40 per cent. capacity for residences, 85 per cent. for business districts, and 95 per cent. for power, another territory with seemingly identical conditions will not show the same averages.

With prevailing transformer weights, it would seem that transformers of over 30-kw. capacity should not go on line poles unless the poles are very strong and well anchored. Fig. 4 shows some commendable construction for supporting a number of heavy transformers. Fig. 5 gives the details of the platform structure shown in Fig. 8. This method can be used where curb or yard space is available, eliminating the need of a vault or the hazardous overloading of poles.

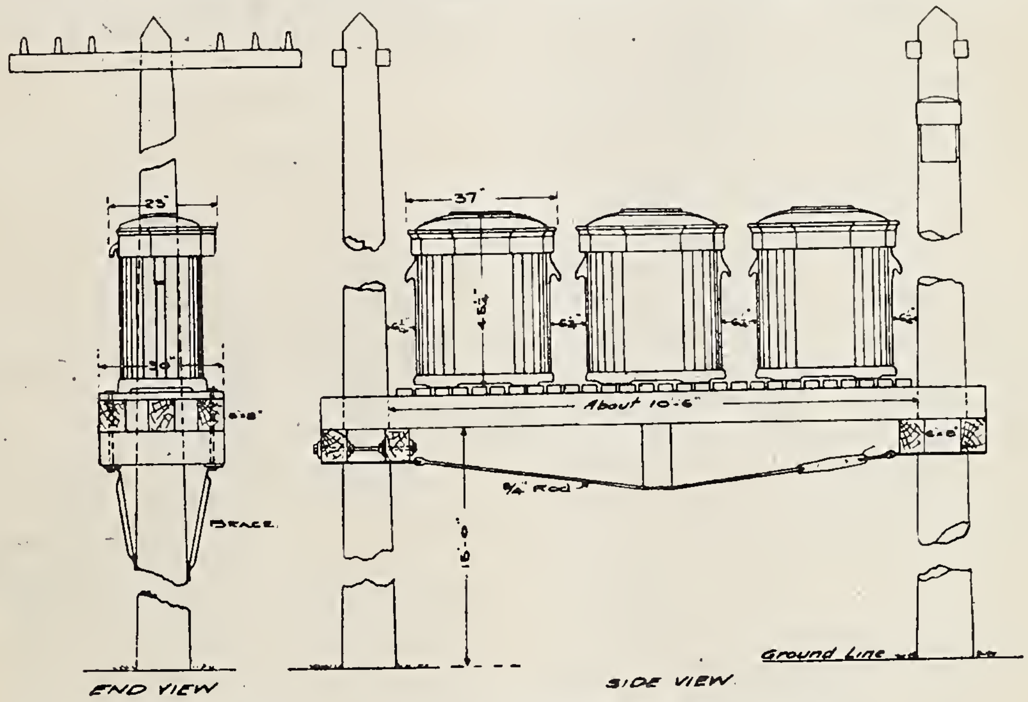


Fig. 5—DETAILS OF PLATFORM SUPPORT FOR TRANSFORMERS

PORCELAIN MATERIALS

Inasmuch as the selection of insulators has some bearing on secondary line construction, mention may be made of a few different practices. One large company has lately been using porcelain insulators almost exclusively for all voltages. The dirt film which any insulator takes on after a short period of service practically puts both glass and porcelain in the same class electrically. The porcelain has greater mechanical strength, can

be procured in dark colors, which make it less of a target, and, owing to recent changes in prices, its cost is about the same as for glass. Fig. 6 shows a porcelain insulator that has been designed to meet the requirements of the company referred to for all voltages up to 6600. This particular design has a capacious tie groove which will comfortably take the larger sizes of cable; yet strength has not been sacrificed to afford the large tie space. Another company uses large, bright-colored porcelain insulators for high-potential circuits that are alive 24 hr. of the day, but resort to glass for the series and low-potential circuits. Still another company has single-petticoat glass insulators on its low-tension lines, while on the 2300-volt and higher multiple circuits glazed porcelain is used. For the arc circuits triple-petticoat high-tension glass insulators are employed. Such plans are adopted so that the circuits may be readily distinguished, to simplify the linemen's work, and further to be a warning to foreign linemen when they happen to be on the electric light poles. It is argued that these index systems are most advantageous, especially in the event of strikes or at other times when it is necessary to break in new men quickly.

Although not a porcelain product, mention may be made here of an oil fuse box developed by one company. A copper fuse wire is placed on a slotted wooden block which is attached to the hinged lid of the iron fuse box. When the lid is closed, suitable contacts engage in jaws attached to the line wire, the fuse being immersed in oil. An oil-sealed duct carries away the vapors generated when the fuse blows. These boxes have been used both overhead and underground at ordinary voltages. No data are in hand regarding the cost of this device; but, as the construction is simple, it is undoubtedly moderate in price.

GROUNDING SECONDARIES

There has been a great diversity of opinion as to the most suitable form of pipe ground clamp. Numerous devices of more or less merit have been put forward, though it still remains for one to be introduced that will meet with general approbation, and a standard set for the whole country.

A solderless clamp has recently been brought out which is unique in that it may be adjusted to any size of pipe. A square-shaped brass binding post with two holes of different size terminates in a screw that fits in a brass saddle-shaped buckle, the sides of which bear on the pipe. The binding post is split from the top about half-way down, with a tightening bolt at right angles to the split to grip the wire. The free end of a tinned-copper strap passes around the pipe and through the slots in the buckle. The other end is secured by doubling through the slots. Screwing down the binding posts tightens the strap about the pipe. A lock nut holds the screw in permanent position. These clamps are claimed to be equally useful for cable connection; also suitable for buried grounds, provided the clamp be painted with asphalt paint.

Neutral Wires: Systems operating in closely settled places and having a large and well-distributed number of neutral wires on three-wire secondary mains should have a splendid opportunity to economize in their grounding work, by installing a continuously grounded neutral throughout. In this scheme the neutral wire of each circuit is heavily grounded at the station to water mains, and additionally grounded to the same at various outside points. The gaps between existing secondary neutrals and back to the station could probably be filled in at comparatively small cost.

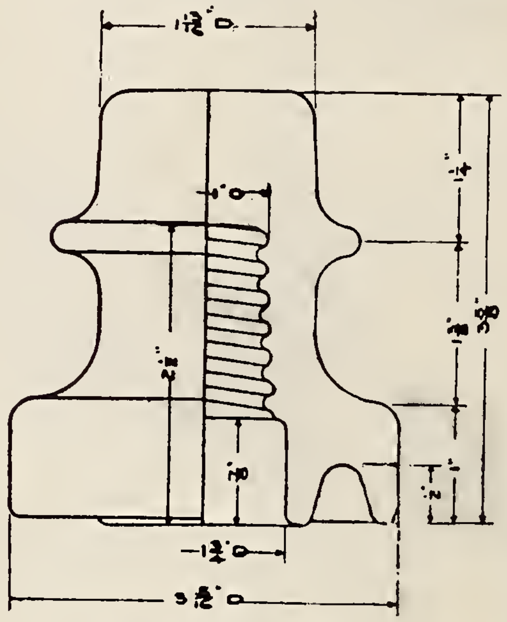


Fig. 6—PORCELAIN INSULATOR

With these favorable conditions the installation of the third wire need not be as costly as it might appear at first thought. In many places there should be a considerable saving over the method of grounding each individual customer; or even in those plants where individual house connections are not carried so far, a part of the system being covered by a few grounds to the neutrals of secondary mains. The saving of such a method would of course be greatly, or even wholly, reduced where only two wire mains existed and the territory to be covered was but sparsely settled. However, if the conditions in the central portion of the territory justify the third wire installation, then the extra leg need not be extended to the scattered zones until a sufficient amount of actual or prospective business warrants such a move. In the meantime, the outlying places could be grounded in the manner best suited to the local conditions.

To illustrate a specific case: A plant had 3000 customers when it first took up the matter of grounding. Assuming an average cost of $6.00 per house ground, the total expenditure with that method would have been $18,000; whereas the actual cost only amounted to $3,000. The conditions in this case were the favorable ones already alluded to, the initial cost being cut down by utilizing existing neutral wires, and any long extensions being made discriminately.

Reliable grounds are insured by this method. The neutral wire not only connects to the neutral of secondary mains, but to all neutrals of independent transformers, and also to those of transformers located in vaults in buildings. Another decidedly favorable feature is that it keeps all the company's property within its jurisdiction, thereby saving much trespassing, and possibly some accidents, on private property, which might lead to legal complications.

INTERIOR BLOCK DISTRIBUTION

Interior block or back-yard distribution affords a means of obtaining business which otherwise could only be taken in the face of serious opposition or at the great cost of putting in street subway. Such installations are generally popular with the public, having in many places met with less antagonism than other forms of distribution, even to the extent of being lauded by the press and strongly encouraged by municipal governments. From the results achieved through its introduction, there may be good reason for the enthusiastic way in which it has been taken up by some companies. However, this impulsive movement should yield to a more conservative view of the matter, as such work has distinct limitations, and certain disadvantages may ensue from a too hasty acceptance. The physical results are of course gratifying to the public and local governments, as the enhanced appearance of the thoroughfares and fronts of private properties is practically the same as afforded by subway. The need of cheap street-cleaning methods is peculiarly felt at this time when there is so much agitation about the injurious effect of wires in trees; and the springing up of shade tree commissions in the larger towns and cities has particularly aggravated the situation.

Aerial lines running through blocks fed by street overhead lines have probably existed in one form or another almost since the beginning of electric lighting, but lately there have been

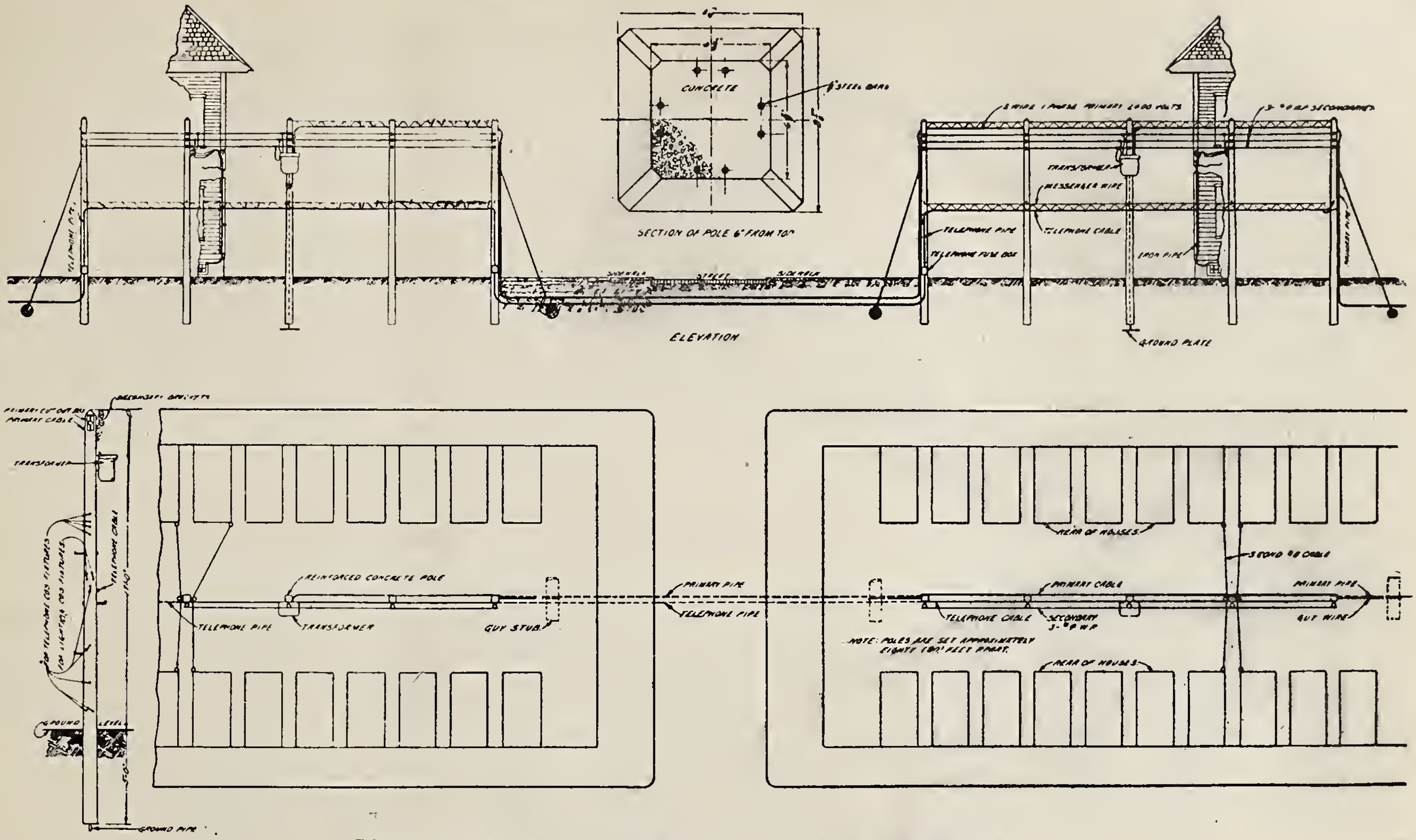


Fig. 7—BLOCK POLE CONSTRUCTION WITH SHORT CONCRETE POLES

special developments devised to meet modern requirements. It should be remembered, however, that there are often disadvantages in connection with such installations. In the first place, they do not entirely do away with poles upon all the streets, and the pleasing effect obtained where they have been installed may in turn create so much objection to regular pole lines that a company may be continually troubled with urgent demands to put everything underground, or at least do away with side street overhead approaches to the interior block districts where they pass through the better residential sections. Another disadvantage occurs where the streets which surround block lines are later lighted by electricity. In that case, if the street-lighting lines are to go overhead, a duplication of pole lines will be necessary. Again, if the streets are to be thus lighted, the city authorities and the public may by that time be so fond of clean streets that only a subway proposition will be considered. If the pole lines are duplicated as before mentioned, the initial construction cost will not only be doubled, but also the line maintenance will be proportionately increased. From another maintenance standpoint, the inaccessibility of backyard lines is a bad point because of the trespassing upon private properties and the difficulty of employees getting into a place after dark. Bad claim cases may arise should an employees be bitten by a dog, or any accident occur on private grounds. Absolute right of way should always be secured for this class of work, as there will be constant need of properly signed permits in order to anticipate spite fights among the customers or, worse, their agreements to disagree with the company.

Where the block to be supplied is approached by overhead lines, an aerial or subway connection is usually made from a street pole to the nearest block pole. The block may be divided by an alley along which the poles may be set, or if there is no alley the poles are best located on the rear property lines, preferably at intersecting lots in order to give the poles neutral locations. In cases where the loads are heavy, primary wires have been introduced into blocks, the transformer being set on a selected pole. Three-wire secondary mains then run through the entire block, the customers' services connecting from the nearest poles to the rear of the buildings. In some cities the meters are always installed in the basement and the wiring contractors bring the wires up through pipe outlets ready for service connection.

Where the approach to the block is by subway, primary lines can be run underground to the transformer manhole situated nearest to the point of entrance to the block to be supplied, the secondary mains entering underground to the nearest block pole. The mains then feed through the block of services connected to the rear of the customers' houses as before described. Cases where yard distribution is effected entirely by conduit systems are so rare that description of them would be of little or no value, because in most places there would be no reason for underground rear connections, as the buildings could be more readily connected by front subway. An exception to the foregoing which might be mentioned is where block distribution is laid out in Edison tube lines in alleys.

Telephone companies have been inclined toward short poles for this class of work, because they are cheaper and less conspicuous than the taller ones commonly used. There seems no reason why the same idea should not be followed in running secondary lines; and it is gratifying to learn that at least one company has demonstrated the practicability of the scheme. A joint agreement sees the poles installed at small cost to each company, with all the succeeding individual benefits in the way of decreased maintenance and contingent expense.

The poles are very short, being but 18 ft. out of ground. The electric cable or wires takes the top position, and where single wires are used they are placed in vertical rows, which arrangement makes them less of an obstruction. The telephone cable is below, but still has ample clearance from both the wires and the ground. If the poles are not stepped the height factor is satisfied. By placing the poles on alternate intersecting property lines, an absolutely neutral location is secured, as each service passes only over the property which it supplies; and where all the houses

are being served the cable loads on the poles are nicely balanced.

Fig. 7 illustrates the same scheme of construction except that concrete poles are used. Where it is feasible to employ this kind of pole, the principal advantages would be: long life, stability, and the comparative economy of construction in many localities where the conditions are favorable to concrete work, and where such obtain, the facility with which a new supply could be secured would be a favorable feature. The company now attempting this work reports that the pole cost is approximately the same as for chestnut; but a considerable reduction under the present cost is expected when certain improvements are effected in the details of manufacture. This departure should certainly appeal to those who are apprehensive of a not far away shortage of chestnut poles, as any development along these lines will help to remove the threatened stringency. Some of the disadvantages are: the increased cost and difficulty in erecting the concrete poles, due to their greater weight, and the fact that ordinary raising methods cannot be employed; and further that the attachments are limited to the number of bolt holes originally built in the pole.

BASEMENT & SIDEWALK DISTRIBUTION

Under certain city conditions regular subway distribution is prohibitive, either because of its cost or opposition to its installation; or again, there are instances where street poles exist, but the services can not be carried overhead. Except as an expedient to cover such conditions, this class of distribution has few advantages. An inflexible condition is apt to be created wherein any changes in the company's equipment, or building or sidewalk alterations, will be made difficult. Permits should be secured which will relieve the company from dependence upon the whims of owners and tenants. Complications may arise that will necessitate discontinuing service at disputed points, thereby breaking the continuity of the circuit and cutting off disinterested parties. In some cities the local electrical bureau and Underwriters' requirements will not permit an underground service to supply more than one building.

One manner of running a subway beneath sidewalks is effected by installing a secondary cable in conduit under the walk, the connections to customers being made within small wooden or iron tap boxes. Sometimes the boxes are sunk below the sidewalk level, a record of their exact location being kept in the operating office so they may be quickly located in case of trouble. In other cases the boxes are supplied with a cover which is set nearly flush with the sidewalk. Fig. 8 shows such an installation, the underground service being led from the terminal pole situated in the centre of the block to a small manhole in the sidewalk. Lead-covered cable in wooden or other conduit is laid under the pavement, with a junction box in front of each place from which the service pipe leads to the service box in the basement.

A refinement of the foregoing is the practice of one company in its manner of handling sidewalk distribution where real estate companies are building whole blocks of houses. The owner desires subway service, but the prospective revenue will often not justify such expenditure on the company's part, so an agreement with the owner is made whereby the owner will do the work inside the curb line in accordance with the plans and specifications submitted by the company. The owner furnishes all labor and material in connection with the same, excepting the cast-iron frames and cover, which are delivered by the company. Either fibre or iron pipe may be used.

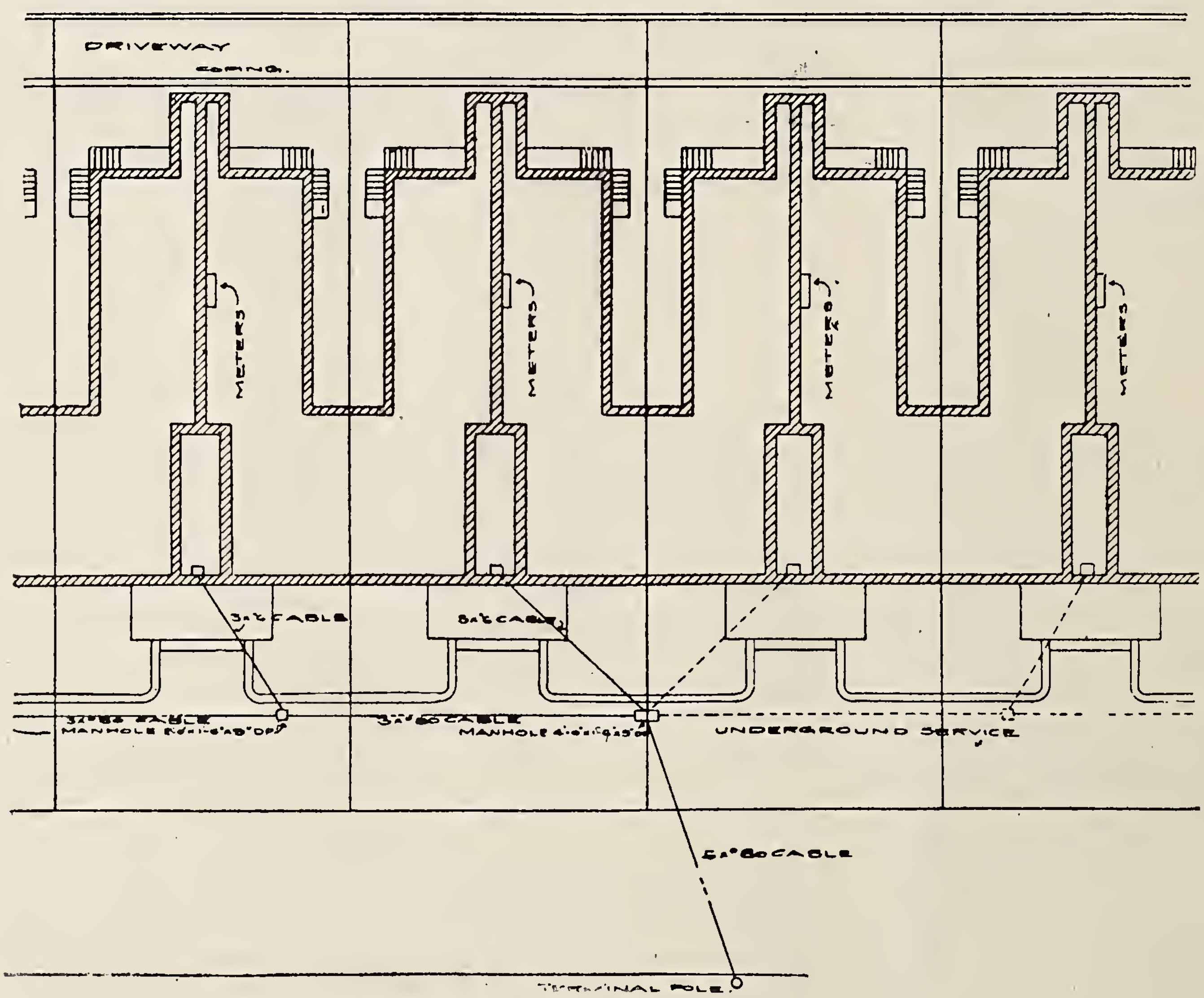


Fig. 8—SIDEWALK DISTRIBUTION

The Present Status of the Arc Lamp for Street and Interior Illumination

N. R. BIRGE

In order to meet the increasing demand of such cities as require a still higher standard of illumination, at the same time conforming to American economic conditions and maintaining a proportionately low operating expense, a direct-current luminous arc lamp operating at 6.6 amperes is being adopted.*

With the exception of the windings, the lamp is identical with the 4-ampere luminous arc now in general use (Fig. 1). By an examination of Fig. 3, which shows the light distribution from both the 6.6-ampere and 4-ampere direct-current luminous arc, the relative values, as well as the similar characteristics, are evident.

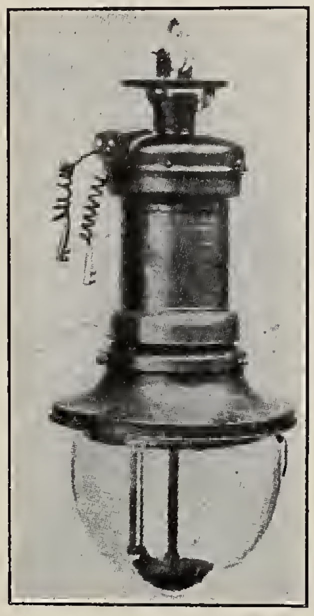


Fig. 1—SERIES LUMINOUS ARC LAMP

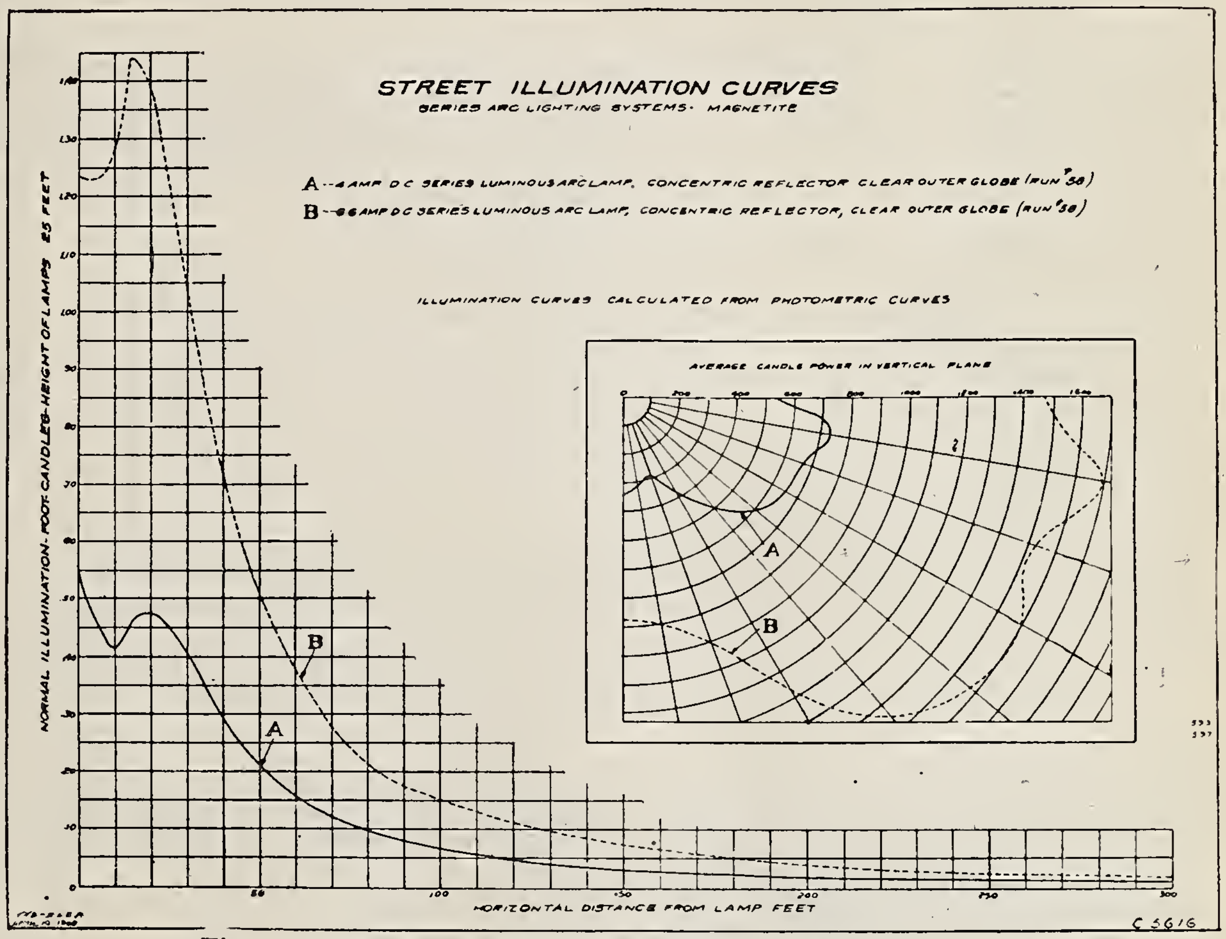


Fig. 3—ILLUMINATION CURVES FOR SERIES LUMINOUS ARC LAMPS

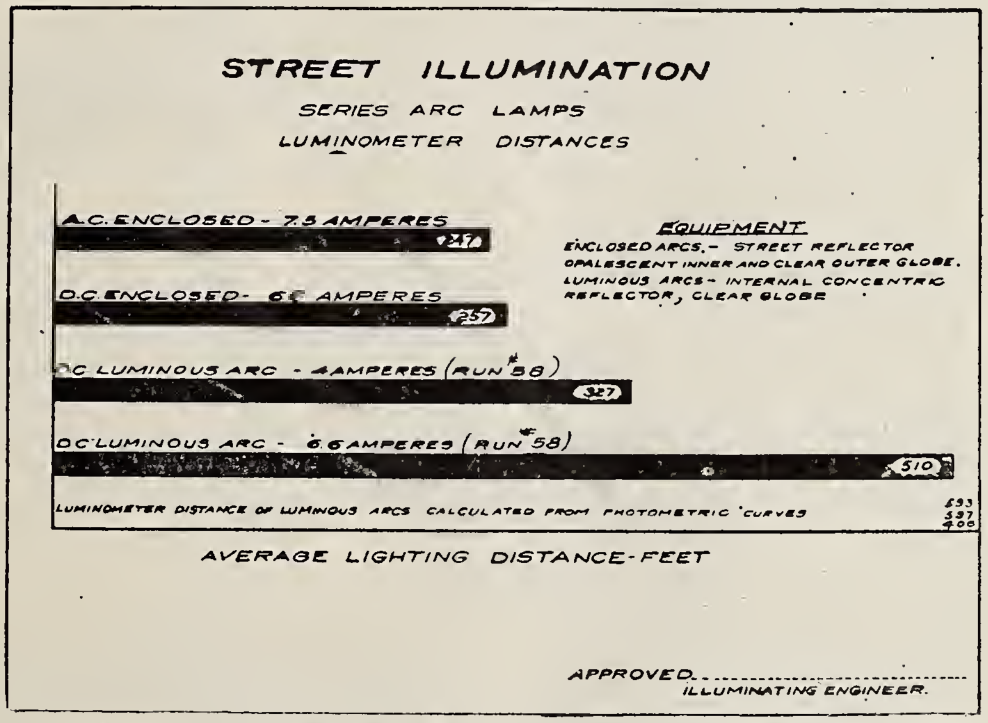


Fig. 4—COMPARISON OF LUMINOMETER VALUES OF LUMINOUS ARCS AND ALTERNATING AND DIRECT-CURRENT ENCLOSED ARCS

Using lower or magnetite electrodes of the same dimensions (5/8 in. by 8 ins.), the life in the first case is from 75 to 100 hours and in the second from 175 to 200 hours. The upper or copper electrodes under the same conditions operate from 2000 to 4000 and 6000 to 8000 hours, respectively, before a renewal is required.

Although the actual cost of operating a system of 6.6-ampere direct-current luminous arc lamps must of necessity be high when compared with a similar system consuming less energy, the cost per unit of effective illumination is in favor of the larger units.

Comparative operating cost per lamp per year of 4000 hours operated from rectifiers, exclusive of repairs on overhead equipment, inspection costs, clerical and storeroom costs, and the like, as these costs would be approximately the same for either system. Interest and depreciation are also excluded, although the first cost of a 6.6-ampere system is about $5.00 per light higher than that of the 4-ampere system.

	6.6-Ampere 510 Watts Terminal	4-Ampere 310 Watts Terminal
Energy at switchboard, 1 cent per kilowatt-hour	$23.24	$14.08
Electrodes	3.75	1.70
Trimming	2.30	1.00
Repairs	.75	.75
Globes	.50	.50
Rectifier tubes	3.00	2.00
Total	$33.54	$20.03

The operating costs given above show a total per lamp of $33.54 for the 6.6-ampere unit, and $20.03 for the 4-ampere unit (exclusive of the items mentioned).

When cost per unit of effective illumination is considered, the larger units show an appreciable economy.

Fig. 3 shows the effective illumination expressed in candle-foot values at a distance of about 300 ft. from the illuminants.

A different method of comparison is shown by Fig. 4. Luminometer values or reading distances of the two

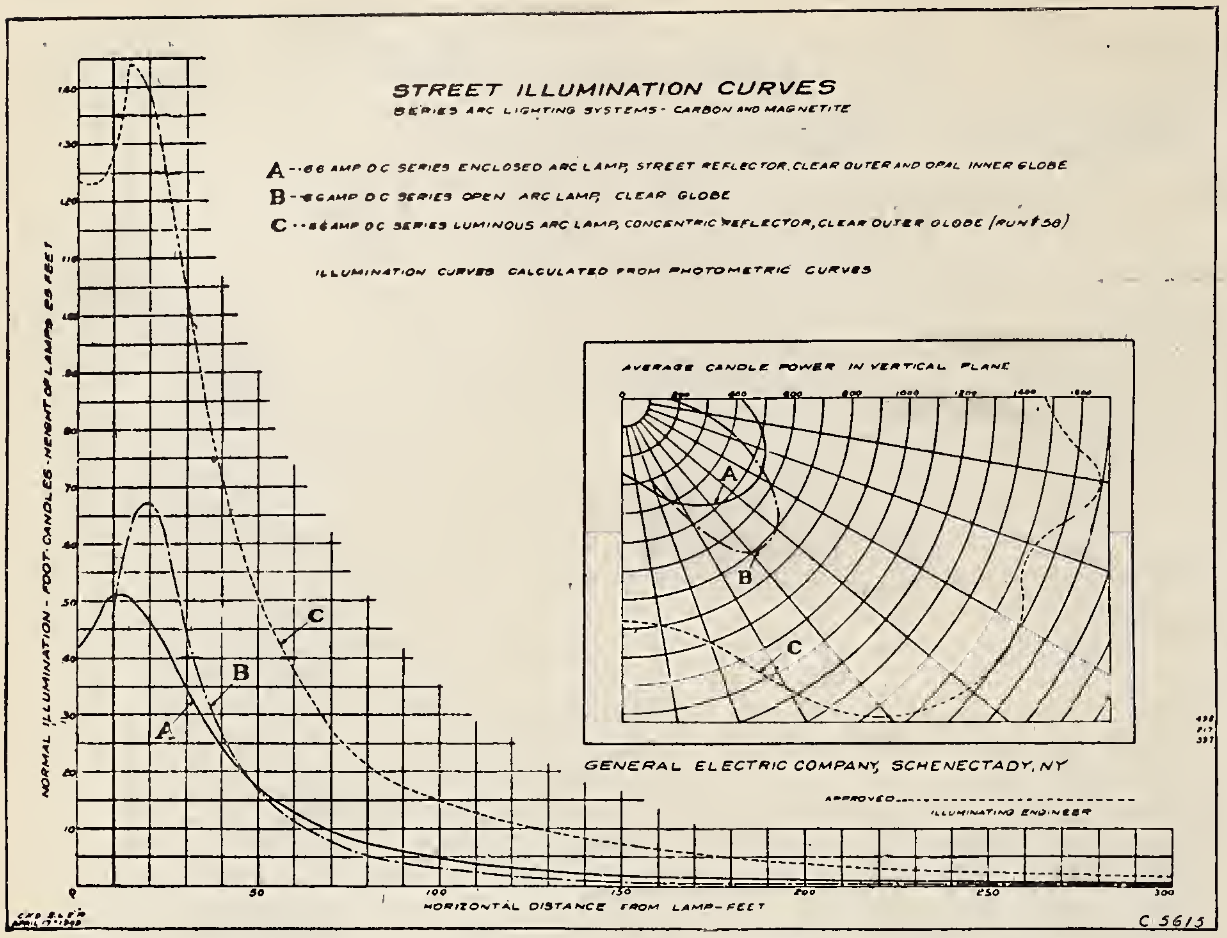


Fig. 5—DISTRIBUTION OF ILLUMINATION FOR 6.6-AMPERE DIRECT-CURRENT, OPEN, CLOSED AND LUMINOUS ARCS

luminous arc are given; values of the alternating and direct-current enclosed arc are also shown for comparison.

Having the 4 and 6.6-ampere luminous arc with their admirable characteristics, and the possibility of a 6000-c-p. flame-carbon arc suitable for operation in series with the 6.6-ampere luminous lamps, the question of proportioning the illumination to sectional requirements is greatly facilitated.

Detailed descriptions of the station apparatus required to operate 4-ampere direct-current luminous arc lamps have been presented with such frequency since its introduction that a repetition is not necessary. The 6.6-ampere direct-current luminous lamp is operated from apparatus of the same general design and characteristics, only slight detailed changes being necessary to provide for the increased current.

Stations using 6.6-ampere Brush arc generators operating arc of the open-carbon type can ill afford to continue such inefficient service. When 6.6-ampere direct-current enclosed-carbon arc are being operated there will be an increased operating cost of about $3.28 per lamp if luminous arc are substituted. But for this small increase a gain of over 100 per cent. in effective illumination is obtained.

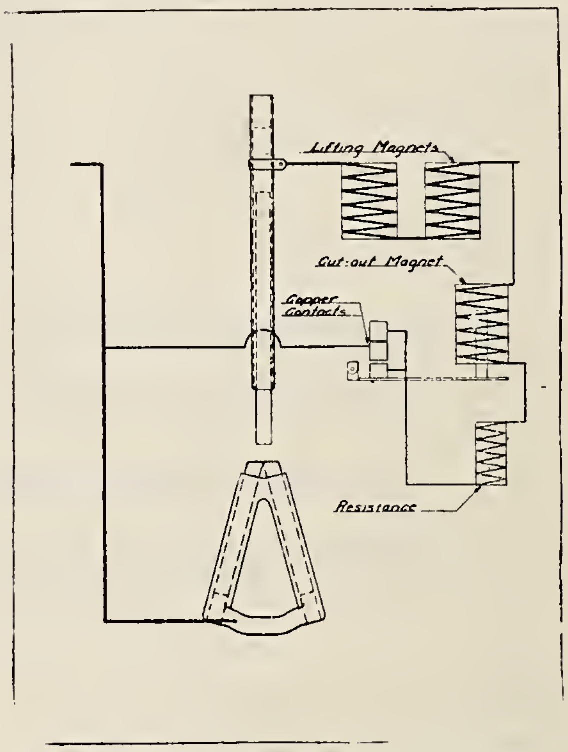


Fig. 8—DIAGRAM OF CONNECTIONS OF ALTERNATING-CURRENT SERIES LUMINOUS ARC LAMP

The following is a detailed tabulation showing the approximate operating cost per lamp per year of a 6-6-ampere direct-current open-carbon arc, a 6.6-ampere direct-current enclosed-carbon arc and a 6.6-ampere direct-current luminous arc—all operated from Brush arc generators direct connected to synchronous motors:

Fig. 5 represents the distribution of illumination and candle-foot illuminating values of the three types of lamps mentioned above.

As the alternating-current luminous arc system, more generally spoken of as the titanium carbide system, has already received more or less publicity, a statement of the present status of this important development should prove interesting.

Fig. 8 is a diagram of the connections. Alternating-current luminous arc lamp. The absence of a shunt winding or other arc voltage-regulating device is apparent. A pair of series magnets, actuating a clutch, lifts the upper (carbide) electrode to a predetermined distance from its lower, and maintains it in such position until the circuit is interrupted by a station switchboard device, which will be described later.

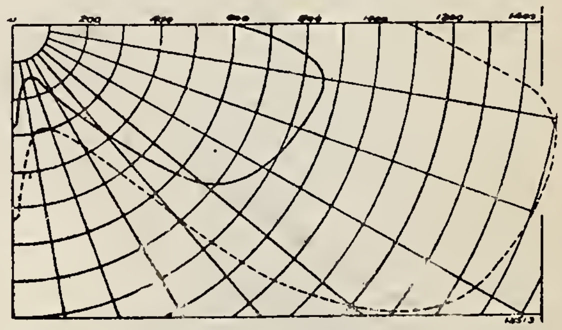


Fig. 9—ILLUMINATION CURVE FOR 3-AMPERE AND 4.5-AMPERE ALTERNATING-CURRENT LUMINOUS ARCS

The arrangement of the lower electrodes is somewhat of a departure from methods in general use. It consists of a suitable frame, in which are held two half-round carbon electrodes kept in abutment at the top by a metal finger forced against their bases. This arrangement maintains, in a simple and effective manner, a focusing arc, with a normal round burning end, without the introduction of a feeding mechanism, which would otherwise be required. As the arc is in the metallic class, suitable drafts are provided which carry the arc fumes into the atmosphere.

The limited number of lamps now in commercial operation and in process of manufacture are designed for operation on 2.5-ampere circuits, but in view of the growing demand for larger illuminating units, lamps of 3 amperes 265 watts and 4.5 amperes 396 watts will be available, the lamp voltage being 110 and power factor 80 per cent. for either lamp. When operating under these conditions, the life of both upper and lower electrodes

Comparative operating costs per lamp per year of 4000 hours, exclusive of repairs on overhead equipment inspection costs, clerical and storeroom expense, etc., as these costs would be approximately the same for any modern system. Interest and depreciation are also excluded.
(Cost based on 100-light installation or over.)

	6.6-Amp. D. C. Open Arc	6.6-Amp. D. C. Enclosed Arc	6.6-Amp. D. C. Luminous Arc
Energy at switchboard, 1 cent per kilowatt-hour	$19.68	$29.72	$29.60
Electrodes	5.50	1.20	3.75
Trimming	6.00	2.00	2.30
Repairs	2.00	.75	.75
Outer globes	.30	.30	.50
Inner globes		.45	
Repairs and renewals on station equipment	1.50	1.50	1.50
Total	$34.98	$35.92	$38.40

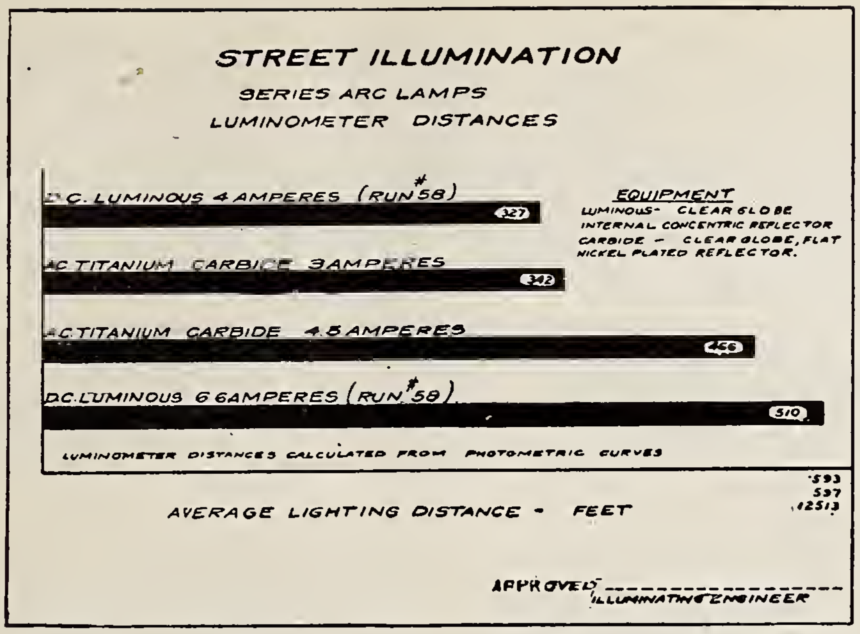


Fig. 10—COMPARISON OF LUMINOMETER READINGS OF ALTERNATING-CURRENT AND DIRECT-CURRENT LUMINOUS ARCS

is approximately 75 and 50 hours, respectively.

Fig. 9 represents the characteristic distribution of illumination from a 3-ampere and 4.5-ampere alternating-current luminous arc, and Fig. 10 compares the luminometer or reading distances of the alternating and direct-current luminous arcs.

Detailed costs of operating the alternating-current luminous arc, as compared with the direct-current luminous arc, are shown in the following tabulation:

Comparative operating costs per lamp per year of 4000 hours, exclusive of repairs on overhead equipment inspection costs, clerical and storeroom expense, etc., as these costs would be approximately the same for any modern system. Interest and depreciation are also excluded.
(Cost based on 100-light installation or over.)

	3-Amp. A.-C. Lum.	4-Amp. D.-C. Lum. Rectifier	4.5-Amp. A.-C. Lum.	6.6-Amp D.-C. Lum. Rectifier
Energy at switchboard, 1 cent per kilowatt	$11.28	$14.08	$17.00	$23.24
Electrodes	10.80	1.70	16.00	3.75
Trimming	2.40	1.00	3.50	2.30
Repairs	.75	.75	.75	.75
Globes	.50	.50	.50	.50
Rectifier tubes		2.00		3.00
Total	$25.73	$20.03	$37.75	$33.54

It will be noted that the cost of the alternating-current luminous electrodes is an unfavorable item of expense. Efforts are being made to secure a material reduction in the cost of these electrodes, with every promise of success when large quantities are manufactured.

Chicago Electric Show

There is every reason to believe that the 1910 Electrical Show, to be held in the Coliseum from January 15th to 29th, will be the most successful and interesting of the several shows the Electrical Trades Exposition Company has given in Chicago. The demand for space is far ahead of any previous year at this time, and many leading concerns have taken more space than heretofore, with the idea of making larger exhibits. Contracts have already been signed with the following concerns: American Steel & Wire Company, Crane Company, Swedish-American Telephone Company, Duntley Mfg. Co., Pelouse Electric Heater Company, General Vehicle Company, Driver-Harris Wire Co., Hurley Machine Co., Neville Illuminating Sign Co., Electric Cleaner Co., National Acme Mfg. Co., Kellor Mfg. Co., Hinde & Dauch Paper Co., Simplex Electric Heating Company, Grand Ledge Clay Product Company, Hoskins Mfg. Co., Mathias Klein & Sons, Appleton Electric Co., Vulcan Electric Heating Company, General Electric Company, National Electric Lamp Association, The Westinghouse Company, North Shore Electric Company, Commonwealth Edison Company, Chicago Telephone Company, and The Electric Shop.

Personal

Mr. C. V. Lansingh, general manager of the Holopane Co., lectured on November 15 before the employes of the United Electric Light & Power Co., New York, on "Electric Illumination."

The H. W. Johns-Manville Co. has recently appointed Mr. H. H. Seaman assistant manager of its New York electrical department.

For seven years Mr. Seaman was associated with the Electric Storage Battery Co., at Philadelphia, Detroit and Cleveland, and for the past two years has been manager of their Atlanta office.

T. I. Jones

In a recent issue of THE ELECTRICAL AGE we published a biographical note of Mr. T. I. Jones and noted that he was "sales manager" of the Edison Electric Illuminating Co. of Brooklyn. Mr. Jones' correct title is general sales agent.—Ed.

News Notes

The Cambria Steel Co. has placed an order with Allis-Chalmers Company for additional generating equipment for the works here. It will install a 3750-k.v.a., 2300-volt, 25-cycle, 3-phase turbo alternator. The turbine will operate under a steam pressure of 125 lb. and with a 27-in. vacuum.

The Great Falls Water Power & Townsite Co. has bought six 200-
The Great Falls Water Power & Townsite Co. has bought six 200 k.v.a., 6600/2200 volt and three 150 k.v.a. 6600/440 volt transformers from Allis-Chalmers Company to install at Black Eagle station, Montana.

The Southern California Edison Co. has ordered six 100 k.v.a. 50 cycle 10000/2200 volt transformers for its power transmission lines from Allis-Chalmers Company.

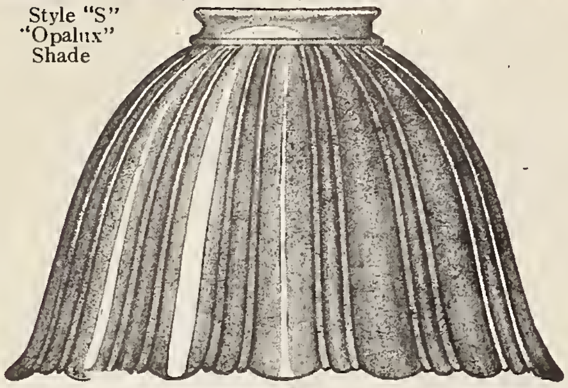
The American Engine Co. of Bound Brook, N. J., report orders for two 500 h.p. angle-compound engines to be used for running centrifugal pumps of the Interborough Rapid Transit Co. power plants. This order is the result of the good performance of similar engines installed earlier in the season.

The American Platinum Works, Newark, N. J., have acquired by purchase the real estate and buildings formerly owned and occupied by the Caffrey Leather Company and J. Liebstein & Sons, located at 225-227-229 and 231 New Jersey Railroad Avenue (Newark), covering half a block on that Avenue—110 ft.—and having a frontage of 250 ft. on Oliver and 30 ft. on Chestnut Streets. The present buildings will be reconstructed and modernized and additional structures will be erected, which, when finished will give this Company one of the most complete plants in the world for the refining of platinum, gold and silver.

A Correction

Through the inadvertence of our editorial department, the beautiful views of the Hudson-Fulton celebration shown in the October issue were not accredited to the New York Edison Co. by whom they had been copyrighted and to whom we were indebted for their use.—Ed.

Style "S" "Opalux" Shade



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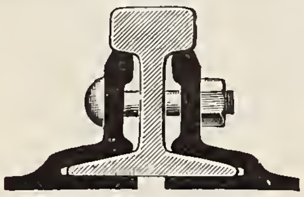

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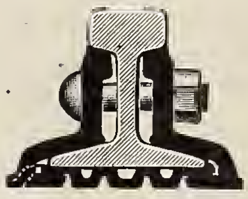

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NOTICE TO ADVERTISERS

Insertion of new advertisements or changes of copy cannot be guaranteed for the following issue if received later than the 15th of each month.

CONTENTS

EDITORIALS

LEADING ARTICLES

Electrical Working of The Mersey Railway

In his paper on the equipment and working results of the Mersey Railway, which is reproduced in this issue from the *Journal of the Institute of Civil Engineers,* Mr. Shaw points out that electric service was inaugurated in May, 1903, because the revenue under steam traction was insufficient to make a commercial success. The traffic conditions called for a train service of 19½ hr. per day, with morning and evening peak loads. In selecting a position for the power-house, the Company was fortunate in having a site practically at the electrical center of gravity of the system, which permitted a distribution system being adopted which depended entirely on the conductor rail, without the assistance of any copper feeders, except the short lengths connecting the rails with the power-station. This condition was realized on the Second Avenue Line of the Manhattan Ry., but is probably unique in the annals of trunk-line electrification, it being usually more economical to space the power- and sub-stations so far apart that copper is required to keep up the voltage. We believe, however, that we are safe in predicting that, thanks to Mr. J. D. Keiley's ingenious circuit-breaker house system, future trunk-line electrification will be accomplished without the use of auxiliary feeders.

The large steam-driven ventilation plant, which was a necessary adjunct to the railway when operated by steam, was superseded by three small electrically-driven fans which cost very little for maintenance. In order to make a comparison between the working results of the railway when operated by steam and electricity, three years' working results under both systems have been analyzed, and for each system an average year of steam and electricity has been taken. The departments of the railway most directly affected by the substitution of electricity for steam were the locomotive and car departments, and the tabulated results show that under electric working these costs have been reduced from 0.209 c. to 0.159 c. per ton mile. With electric traction 1 lb. of fuel costing $1.87 per ton moved 1 ton of load 2.04 miles at an average speed of 22¼ miles per hr.; whereas with steam the same weight of fuel costing $3.84 per ton moved the same load 1.98 miles at an average speed of 17¾ miles per hr. The effect of electric traction on the maintenance of the permanent way has been to reduce the cost of maintenance per ton mile from 0.0372 c. to 0.0159 c. per ton mile. As regards the life of the rails under the two systems, the average rolling load over the track before the rails required renewal was increased from 36,000,000 to 53,000,000 tons. The substitution of electrically-driven pumps for the working of the hydraulic elevators decreased the cost per elevator mile from $1.70 to $0.60. The effect of electric operation on the working results has been to decrease the total cost of working and maintaining the whole of the locomotive and engineering departments from 0.425 c. to 0.272 c. per ton mile. The total costs of the railway, including general charges, but exclusive of interest on additional capital for electrification, were reduced from 0.615 c. to 0.43 c. per ton mile. The average speed of the trains, including stops, was increased from 15.6 to 19.9 miles per hr., and the number of ton miles per annum from 48,000,000 to 75,000,000, while the total expenses per ton mile, after allowing interest on additional for electrification, were reduced from 0.615 c. to 0.525 c. In the half-year ended June 30, 1908, the number of passengers carried was more than twice as many as in the last half-year of steam working. The seat miles run per passenger showed a decrease of 30 per cent., and the passenger receipts per seat mile an increase of 26.5 per cent., while the ratio of expenses to receipts decreased from 95.3 per cent. to 69.8 per cent. This was accomplished in spite of the fact that just before electric working began the corporation of Birkenhead opened an extensive system of electric tramways, which had the effect of considerably reducing the Company's receipts.

The reader should note that the figures in this editorial are based on the American ton of 2000 lb., while those in the article itself are based on the long ton of 2240 lb.

Electrical Operation and Permanent-Way Maintenance

In his admirable paper read before the Institution of Civil Engineers and reproduced in this issue, Mr. C. A. Harrison deals with the effect of electrical operation on permanent-way maintenance as illustrated on the Tynemouth branch of the Northeastern Railway of England. He shows that, while there was some increase in the cost of permanent-way maintenance, following the introduction of electrical working, the improved traffic facilities rendered possible substantial economies in trackwork in other directions. On the Tynemouth line the introduction of electrical working had caused a steady increase of passenger load, and the present volume of traffic could not be dealt with by any other method without substantial increase of terminal accommodation. In any case, the additional cost of maintenance has not proved to be a heavy one. Instances had occurred at crossings, which under steam conditions had lasted nine years, requiring renewal at the end of five years. To meet the conditions of wear, especially on curves and cross-

ings, Sandberg and manganese rails have been installed, but it remains to be proved whether the additional cost involved would be justified by the increase in life obtained. With regard to the maintenance of the electrical equipment of the track, he is of the opinion that $250.00 per annum per mile of single track should cover all likely contingencies.

While Mr. Harrison's figures are not entirely applicable to working conditions in America, they constitute the best exposition of the subject which has ever appeared, and we recommend a careful study of them to all of our readers who are interested in electric traction.

Western Electric-General Electric Agreement.

Announcement at another page of an agreement between the Western Electric Company and General Electric Company, whereby the Western Electric Company sells its power apparatus manufacturing business to the General Electric Company, is the most important commercial transaction of the last decade, and is of distinct benefit to each Company.

With the rapid growth of the telephone business, the Western Electric Company found itself this year in need of more shop facilities, which could be met only by taking over the space heretofore used in the manufacture of power apparatus, or by the building of additional shops. The exceptional favor which the Company's power apparatus has met with in the hands of consumers put the Company in such a position that it would have had almost to double its already very large plant used in the manufacture of electrical machinery. And both of these demands were urgent with the rapidly-rising sales of the Company. The easy solution of the difficulty was to use the space heretofore used in the manufacture of power apparatus in the expansion of the telephone plant, and to have their electrical machinery manufactured for them.

A subsidiary reason for the agreement has also existed. The patent relations of the two companies have been complicated and have led to much confusion. The whole situation is now happily cleared up.

The apparatus to be sold hereafter by the Western Electric Company will be sold under the well-known "Hawthorn" name-plate. It will be made under the general supervision and specifications of the Western Electric Company.

It is further understood that the General Electric will continue to manufacture for the Western Electric Company the Western Electric type of machines and furnish repair parts for them until such a time as the demand for them shall have ceased, so that customers of the Western Electric Company will be amply taken care of.

"Electric Traction on Railways," by Philip Dawson, M. Inst. C. E., M. I. E. E., M. I. Mech. E.; 855 pages; 60 illustrations: Price, $9.00; D. Van Nostrand Co., New York.

The D. Van Nostrand Co. is to be congratulated on the class of books which they have recently been issuing. A series of books like Frank Koester's "Steam Electric Power Plants," W. A. Del Mar's "Electric Power Conductors," H. A. Foster's "Electrical Handbook," M. Solomon's "Electric Lamps," and the book which is the subject of this review, is sufficient to raise the prestige of any publishing house to the very front rank.

Mr. Dawson's book is already the standard work on the subject and, although written by an Englishman, the author's point of view is generally so broad that it is equally useful to an American. It must be remembered, however, that the author is, to use Mr. Murray's phrase, a "Single-phase Man." The battle of the phases is fought and won, of course, in a very one-sided way and there are other evidences that his views, although broad, are not always impartial. When so noted an expert produces a pretentious work of this kind, we should have expected a greater amount of original material and greater number of original statements of opinion, and we must confess that the work is greatly marred by the apparent willingness of the author to take for granted, without personal investigation or expression of opinion, any results of others to which he could refer.

The value of the work is greatly reduced by the large number of errors which have crept into this edition, of which only a few examples are given below:

On pages 440-441 Mr. Dawson attempts to prove the usual formula for the self-induction of a pair of parallel wires. On page 439 he gives (in Fig. 303) a correct representation of the magnetic fields around two parallel wires and their resultant field, showing clearly that this extends *beyond* the axes of the two wires, yet on page 441, in trying to prove the self-induction formula, he calculates the total flux by integrating the curve of resultant field between the axes of the wires, neglecting the fact that the curve goes beyond. The final result is correct, but only because the above-named error is offset by another error. He assumes that the self-induction of a pair of parallel wires of *finite size* is the flux due to unit current. This is wrong, as it applies only to wires of *infinitesimal* cross-section. All this is clearly stated on page 321 of Del Mar and it is about time for authors to "get onto" this fact, so strongly emphasized by J. J. Thomson. On page 27, velocity is denoted by v on the second line, while the same letter is used on the eighth line to represent the change of velocity in time t. The first formula on page 75 contains the expression $\frac{1}{2}$ m a^2 p^2, where a = angular velocity and p = radius of gyration. The following paragraph states that a^2 p^2 has the dimensions of a velocity, an obvious error, as a^2 p^2 has the dimensions of the square of a velocity. On the same page the energy of translation is expressed both as E_t, and E , and the angular velocity, previously expressed by a, is later on the page expressed by A. This same page has an error in its fourth equation, v_2 being written instead of v^2. Such a series of errors on one page is quite a serious matter, especially when the book is put in the hands of a student who is unable to detect them. While this page is especially noteworthy for its errors, there are numerous slips of the same kind on other pages containing mathematical matter. Mr. Dawson also reduces the value of his remarkable work by errors in quotation. For example, Chapter XIII is largely quoted from a paper by Mr. C. A. Carus-Wilson, which may be found in Vol. CLXXI, 1908, of the Proceedings of the Institution of Civil Engineers; comparison of the original and the quotations from it reveal the following discrepancies:

Page of McDawson's Book	Line	Quotation.	Original.
420	2	240	2,240
420	18	0.0972 to 0.008	0.00972 to 0.008*
420	24	0.077	0.0077*
421	19–20	1 in 250	1 in 250 and 1 in 400
421	30	1 mile	10 miles

Enough with fault-finding or the reader will get an entirely wrong impression of the book.

Considered in the broadest way, Mr. Dawson's book is a summary of all that has appeared in the proceedings of the technical societies and in the technical press on the subject of electric tractions during the last decade. In addition to this, it contains some information about the London, Brighton and South Coast Railway which has not previously appeared in print. This material is admirably arranged in logical order and is clearly presented in an entertaining way, making it of interest to the student and engineer. To one who has closely followed the literature of the day on electric traction, a perusal of this book is like seeing an album of

pictures of familiar faces, and one has the despondent feeling that, after all, it is not worth while to carefully collect all the current literature, if some one like Mr. Dawson is to come along and present it all in convenient shape in a single volume!

Chapter XXVII, on Financial Considerations, is one of the best in the book, being possibly the aspect of the subject with which Mr. Dawson, as a consulting engineer, is most familiar. This chapter ought to appeal to directors and other railroad officials as much as to the engineer. The table opposite page 814 (No. LXXIII.) is particularly interesting, giving, as it does, a very thorough itemized account of the costs of operating the railways in and about London. This table shows the following total working expenses per car mile from June, 1908, to June, 1909, for six London railways to be as follows:

	Pence.	Cents.
Central London	5.10	10.20
City and South London	2.85	5.70
Baker St. and Waterloo	5.59	11.18
Great Northern, Piccadilly and Brompton	4.83	9.66
Charing Cross, Euston and Hampstead	4.86	9.72
Great Northern & City	5.43	10.86

The reasons for these differences are clearly shown in the table.

We have pleasure in recommending the book to all interested in the broad field of electric traction.

Distant Control Switchgear

STEPHEN Q. HAYES

PART I

The steady increase of late years in the capacity of power plants and the voltage of transmission systems has been the cause of the great and extended adoption of distant control switchgear for the handling of the circuits of large capacities and high voltages in such plants.

In earlier years where the amounts of power were small and the voltages comparatively low, the various generator and feeder circuits were controlled by switches located on the station wall. The next step in advance was the assembling of all of the switches, instruments, etc., on a framework of wood, which gave rise to the term "switchboard."

Owing to the fire hazard of this wooden construction, slate and marble slabs on an iron framework soon replaced the wood and in the gradual evolution of design the panel switchboard came to be the American standard for moderate-sized plants, while in Europe the trend was more toward cabinet construction for small equipments and pedestals and desks for larger ones.

As the amounts of power to be handled increased a point was ultimately reached when it became necessary to take greater space for the switches, circuit-breakers and similar appliances than could be found available on the so-called panel switchboard and distant control apparatus was the natural solution of the problem.

While in America there is no hard and fast rule as to just when and where distant control switchgear should be employed, it is becoming general practice in alternating-current installations of 2200 volts and above, and of more than 2500-kw. capacity, seriously to consider the use of distant control for the oil circuit-breakers and similar appliances. As the voltage or the amount of power increases, the use of distant control equipment becomes more nearly universal. In some cases, even of smaller capacities or lower voltage, distant control is advisable and is occasionally used for direct-current plants.

In Europe hand-operated distant control apparatus is used even in plants of comparatively large capacity, while in America some auxiliary air or electrical operation, is employed source of power, such as compressed in practically all alternating-current generating stations of a capacity of 10,000 kw. or over, and in many smaller ones. Such auxiliary control is usually found advisable, owing to the amount of power to be handled; the physical exertion necessary to

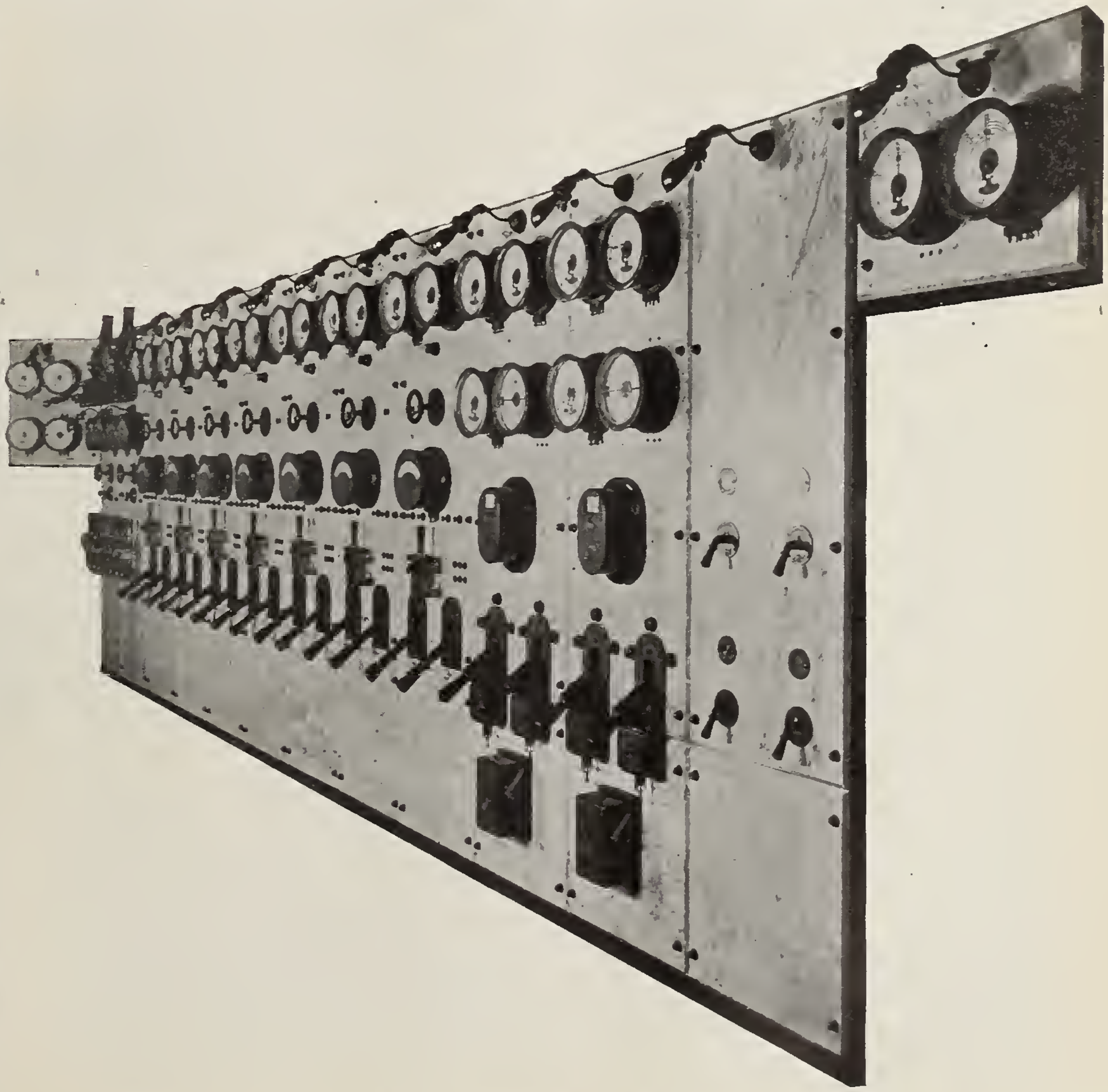


Fig. 1.—AMERICAN (WESTINGHOUSE) PANEL BOARD, HAND OPERATION, ATLANTA WATER POWER COMPANY

manipulate large apparatus; the number of circuits to be controlled; the high voltage used; the advisibility of concentrating the control of widely separated devices, or for other cogent reasons.

The consideration of distant control switchgear naturally divides itself under the following heads:

1ST.—Switchboards comprising the panels, desks, pedestals, etc., on which the controlling devices, instruments, etc., are mounted.

2D.—Apparatus for distant control, such as switches, circuit-breakers, rheostats, etc., with the controllers and similar devices used in connection with such an equipment.

3D.—Layouts comprising the arrangement of the structures for the breakers, bus bars, etc., in the stations with the relative location of generators, transformers, feeders and lines.

While considering these various sections, particular attention will be paid to the following features: radical or epochal improvements; increase in reliability; economy in space; safety in operation; saving in time.

It is, of course, impossible to cover all of the changes that have taken place in the design of switching appliances and their accessories in the space of an article of reasonable length and it is equally impossible to describe the present apparatus of all manufacturers. For this reason this article will confine itself to some of the more recent examples of distant control equipments in America and Europe with a few examples of older equipments to show the evolution of design.

Owing to the close inter-relation between switchboards and apparatus where hand-control is used, and between apparatus and layouts where auxiliary control is used, the various divisions will necessarily overlap more or less and the descriptions and illustrations will really apply in some cases to two or more divisions, but as far as possible the divisions will be kept separate and the divisions will be still further broken up into sections more or less overlapping, but in general as follows:

1ST—SWITCHBOARDS.

A—General features.

B—Panel Boards of American design.

C—Panel boards of European design.

D—Cabinet boards of European design.

E—Cabinet boards of American design.

F—Pedestal boards of American design.

G—Pedestal boards of European design.

H—Desk boards of European design.

I—Desk boards of American design.

2D—APPARATUS.

A—General features of manual operation.

B—General features of pneumatic operation.

C—General features of electrical operation.

D—Manually operated air-break main switches and breakers.

E—Pneumatically operated air-break main switches and breakers.

F—Electrically operated air-break main switches and breakers.

G—Manually operated oil-break main switches and breakers.

H—Pneumatically operated oil-break main switches and breakers.

I—Electrically operated oil-break main switches and breakers.

J—Manually operated air-break disconnecting switches.

K—Pneumatically operated air-break disconnecting switches.

L—Electrically operated air-break disconnecting switches.

M—Manually operated field switches.

N—Electrically operated field switches.

O—Manually operated field rheostats.

P—Electrically operated field rheostats.

Q—Control switches and indicators.

R—Auxiliary apparatus.

3D—LAYOUTS.

A—General features.

B—Manually operated air-break equipments.

C—Pneumatically operated air-break equipments.

D—Electrically operated air-break equipments.

E—Manually operated oil-break equipments.

F—Pneumatically operated oil-break equipments.

G—Electrically operated oil-break equipments.

H—Details and auxiliaries.

DIVISION I—SWITCHBOARDS.

Section A—General features:

In designing the switchboard equipment for any plant there are two main features to be considered—the general connections desired and the means necessary to obtain them.

When considering the main connections desired in any plant it is necessary to weigh carefully the relative values of flexibility and simplicity, and to balance up the cost of apparatus needed only in an emergency against the loss that might occur if provision were not made for such a contingency. The general problem resolves itself into obtaining the maximum amount of flexibility and safety against shut-down with the minimum outlay for apparatus and building. As the cost of the apparatus and space it occupies increases rapidly with increase in voltage many ingenious and effective schemes have been adopted for reducing to a minimum the number of high-tension breakers, switches, etc.

The relative advantages of the single bus-bar system, double bus-bar system, group system, ring system and their combinations and modifications have to be carefully considered, and the system finally decided on is usually a compromise between flexibility and cost. European practice is almost invariably in favor of the ring system of bus bars as allowing any section of bus to be cut out for inspection and repair, while American practice is almost as invariably opposed to the ring on the idea that it is not necessary and that the same

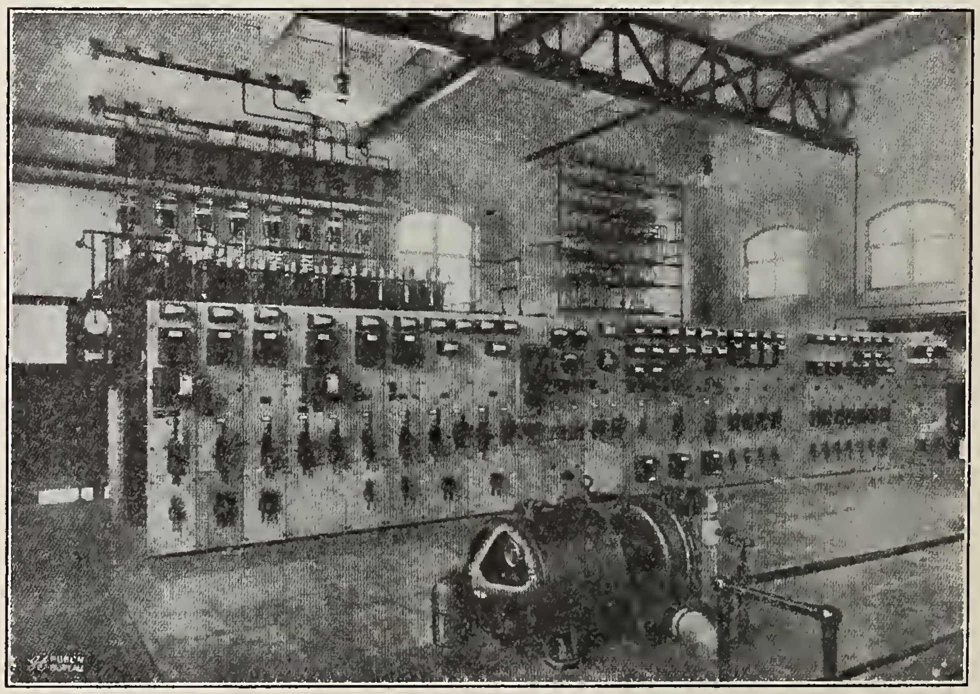


Fig. 2.—AMERICAN (G. E. CO.) PANEL BOARD, HAND OPERATION, GREENFIELD ELECTRIC LIGHT & POWER CO.

or even greater amount of flexibility can be obtained by other arrangements of the same amount of apparatus. In some very large plants in America of recent design the ring system is being considered with more favor and in a new plant of 165,000-k.v.a. capacity, at 11,000 volts, being supplied to Rjukanfos in Norway, the ring system has been discarded for an arrangement of circuits that normally has each 8250-k.v.a. generator supply current to its own feeder with provision for connecting to either or both of two sectioned bus bars.

Where the power plant is provided with step-up transformers for high voltage transmission it is usually advisable to have the transformer banks equal in capacity to one, two or three generators, and to make the capacity of the lines equal to one or two transformer banks. This permits independent operation with the minimum amount of apparatus and the maximum amount of flexibility.

In practically all large plants in America the high-tension circuits are controlled by electrically operated oil switches or oil circuit-breakers, and the electrical operation is often extended to the field rheostats, field switches, governor motors, etc. The controllers or switches for operating this apparatus, together with the meters for indicating and recording the current voltage, etc., of the various circuits, are mounted on a switchboard of the panel type on pedestals or control desks, depending on individual tastes and local conditions.

In Europe individual control desks or pedestals for the generators and cabinets or similar devices for the transformers and feeders are more nearly standard, and the high-tension oil switches are usually manually operated by a shaft or rope transmission.

In America for switchboard panels, pedestals, desks, etc., the material employed is ordinarily blue Vermont marble or slate, with either oil or marine finish, although white Italian marble, pink Tennessee marble or black enamelled marble or slate is sometimes employed.

In Europe white marble is used principally, although where control desks are employed the apron of the desk is often made of cast iron with the instruments set in it, where American practise uses slate or marble.

Owing to the difficulty of matching polished blue Vermont marble and removing oil stains, scratches, etc., the marine or oil-finished slate is rapidly growing in popularity in America, as the question of matching is then a simple one and a little paint or vaseline will take care of any oil spots, scratches or other imperfections. This dull-black finish has the further ad-

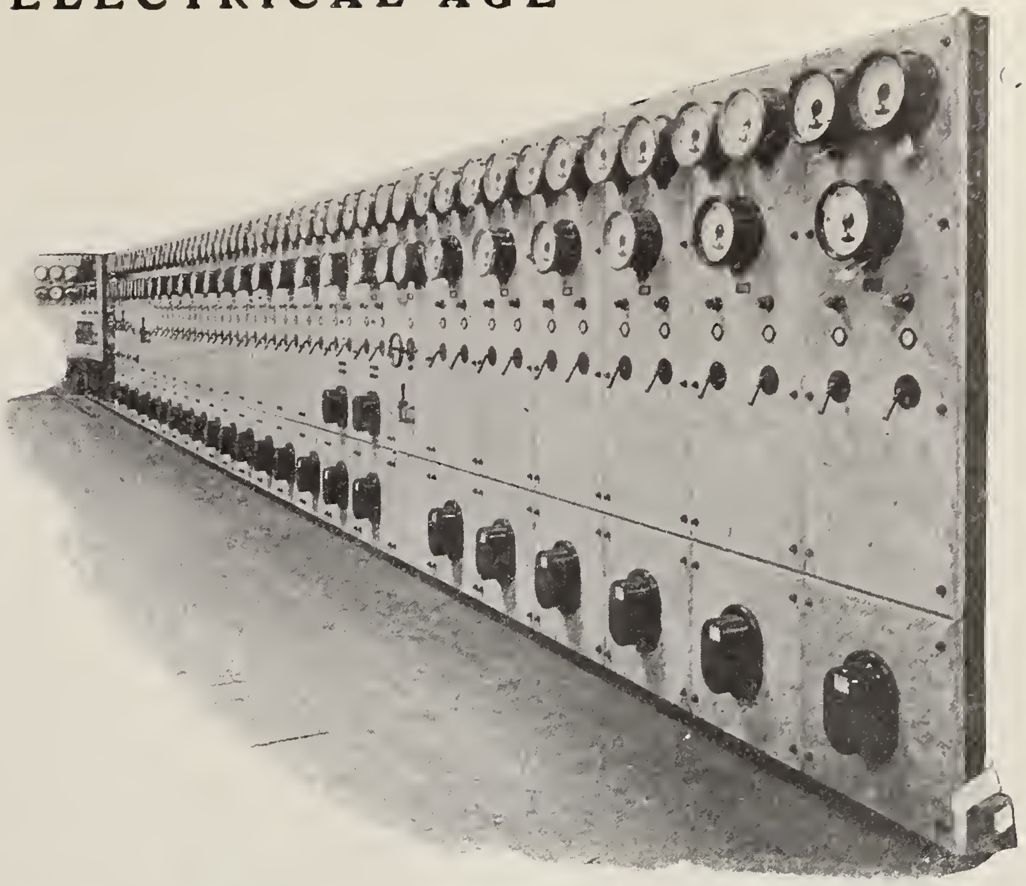


Fig. 3.—AMERICAN (WESTINGHOUSE) PANEL BOARD, ELECTRICALLY OPERATED, LOUISIANA PURCHASE EXPOSITION

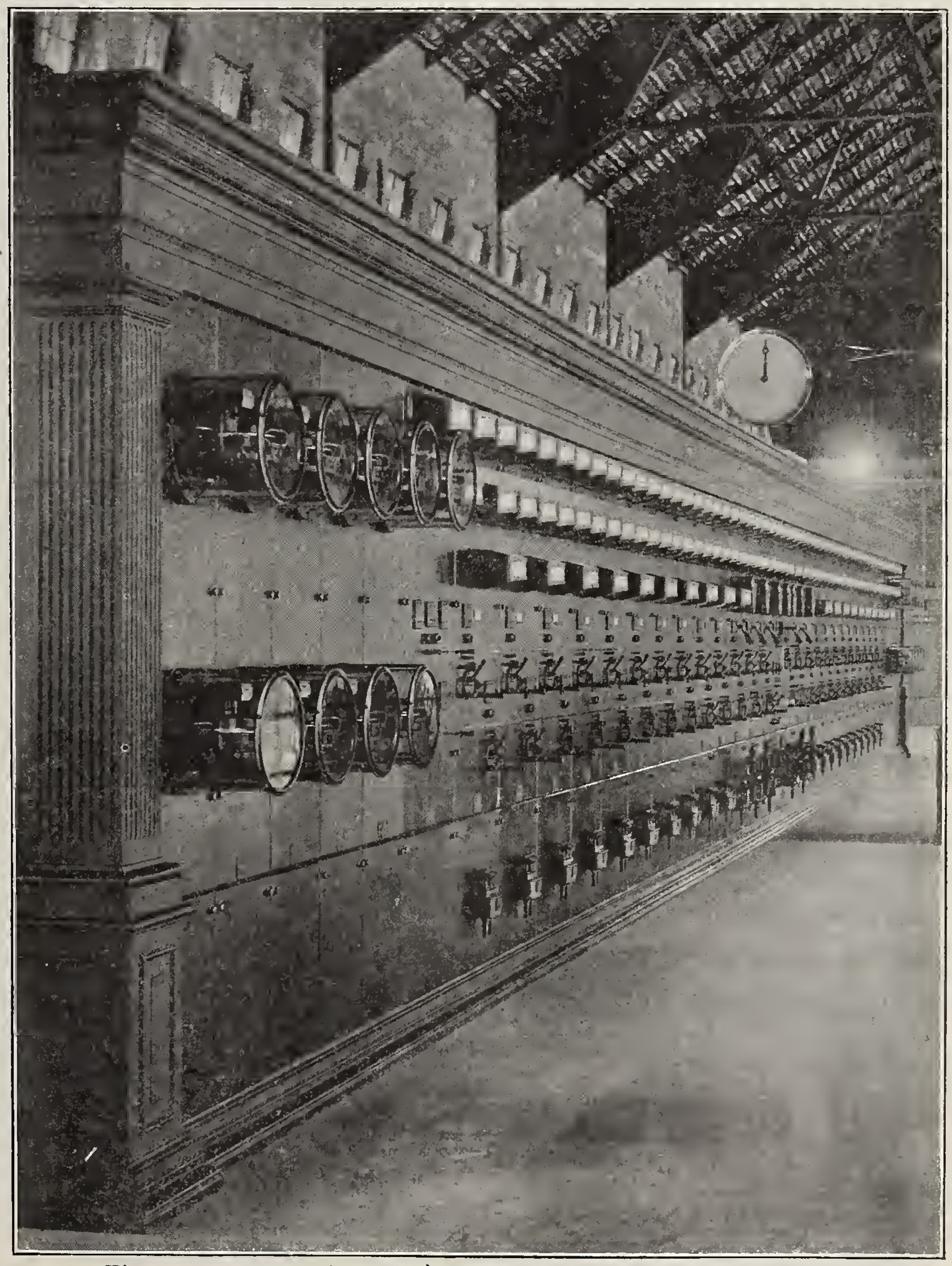


Fig. 4.—AMERICAN (G. E. CO.) PANEL BOARD, ELECTRICAL OPERATION, CANADIAN NIAGARA POWER CO.

vantage of not reflecting light in the eyes of the attendant and the controlling devices, instruments, etc., stand out clearly against the dark background.

Section B—Panel boards of American design.

10,000-volt circuits, two exciters, three 2300-volt generators, six 3-phase and single-phase 2300-volt power and lighting circuits and three mercury rectifier circuits. The panels are mounted on a pipe framework with the 2300-volt oil switches directly back of the panels and the 10,000-volt switches in brickwork cells. The bus bars are supported on pipe framework.

Panel switchboards for electrical operation are of very similar design in most cases to the panel boards for manual operation.

Fig. 3 shows the large panel board of blue Vermont marble with round pattern instruments supplied in 1904 by the Westinghouse Company to the Louisiana Purchase Exposition in St. Louis, and was used to control three 125-volt exciters, four 2000-kw., 6600-volt, 3-phase, 25-cycle generators, two 4000-kw. incoming feeders and seventeen outgoing feeders. These panels were provided with the usual equipment of instruments and the breakers were electrically operated.

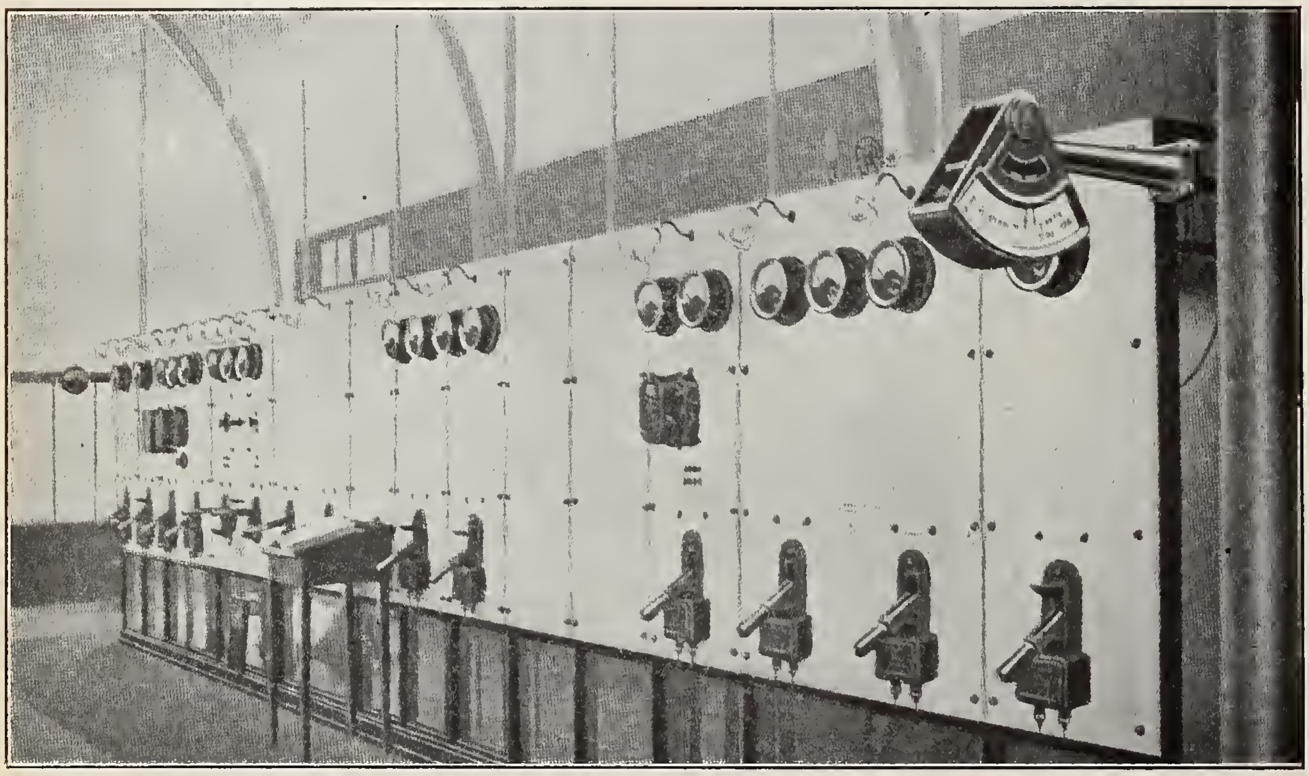


Fig. 5.—EUROPEAN (WESTINGHOUSE) PANEL BOARD, HAND OPERATION, CLERMONT FERRAND

It is customary to mount the usual equipment of instruments for the generators, transformers, feeders, etc., on the same panel as the operating handles of the oil switches or the controlling devices for the electrically operated apparatus. This type of construction is employed where the number of units is comparatively small or where the space needed for instruments is so great that any attempt to reduce the length of the operating board will result in placing the instruments at such a distance from the operator that it will be difficult for him to see the scales and pick out the meters belonging to any one circuit.

Fig. 1 shows a panel type of switchboard with hand-operated oil switches and circuit-breakers built by the Westinghouse E. & M. Company for the Atlanta Water Power Company for the control of two exciters, seven 1500 kw., 2200 volt generators, two banks each of three 1500 kw., 2200/22,000 volt transformers and two transmission lines. A double bus-bar system was used and any generator or transformer bank could be connected to either or both sets of bus bars. Panels are of marble mounted on angle iron framework with the oil circuit-breakers in a masonry structure.

Fig. 2 shows a panel type of switchboard with hand-operated oil switches built by the General Electric Co. for the Greenfield (Mass.) Electric Light & Power Co. for the control of eight

Fig. 4 shows the panel board of oil-finished slate with horizontal edgewise instruments supplied by the General Electric Company to the Canadian Niagara Power Company at Niagara Falls, Ontario, and used for the control of five 7500-kw., 3-phase, 25-cycle generators and twenty feeders. This board comprises five generator panels, twenty feeder panels, ten recording wattmeter panels and three bus bar interconnecting panels. Each panel is distinct and contains no instruments or switches except those belonging to the particular feeder or generator in question. Each panel contains all of the instruments and switches involved in any operation which the attendant has to make.

Section C—Panel boards of European design.

Fig. 5 shows a panel switchboard supplied in 1904 by the Societe Anonyme Westinghouse for the sub-station at Clermont Ferrand in France for the control of two lighting circuits, one generator circuit, three lighting transformer circuits, one bus junction circuit, three power transformer circuits and three power feeders. The switchboard is of white marble with the usual complement of instruments, while the 3000-volt oil circuit-breakers are placed in a structure of re-enforced concrete located in the basement.

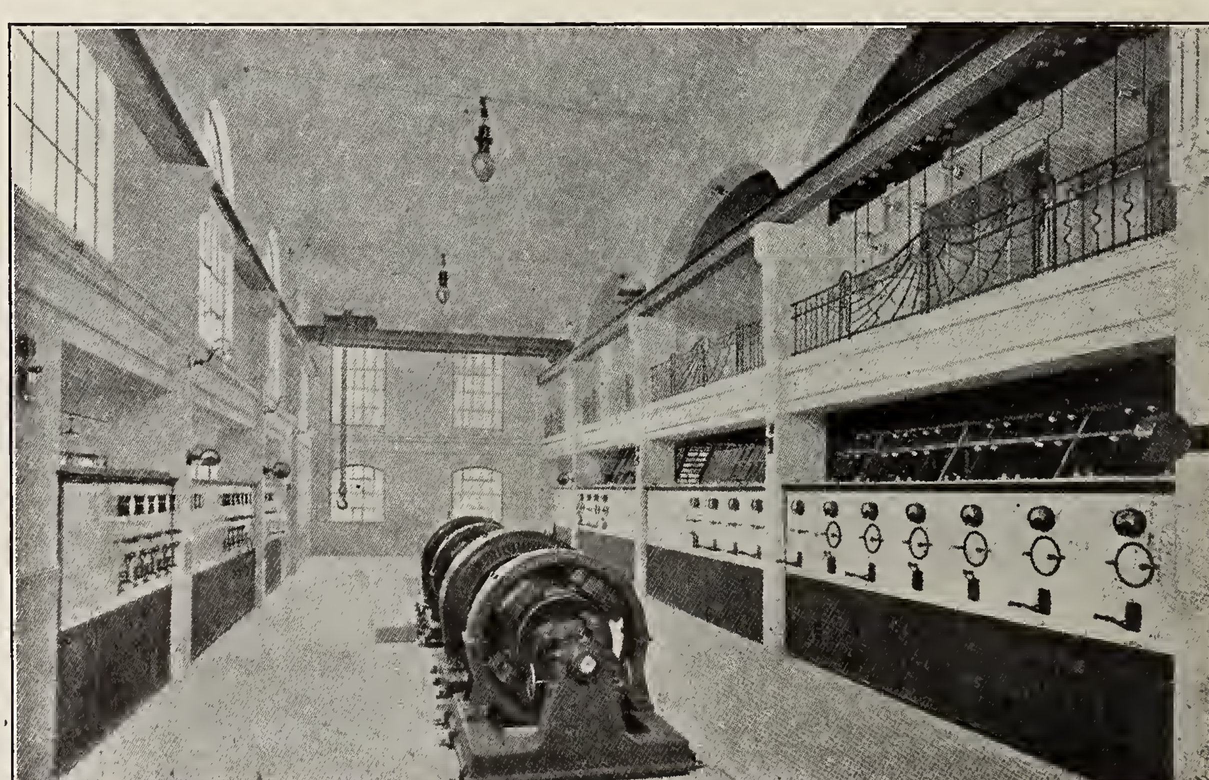


Fig. 6.—EUROPEAN (OERLIKON) PANEL BOARD, HAND OPERATION, ENGELBERG LUCERNE

Fig. 6 shows a panel switchboard supplied by the Oerlikon Company for

the Steghof Sub-station of the Engelberg Lucerne transmission in Switzerland. This switchboard forms practically a wall to the machine-room and the 29 panels of white marble along the right-hand side of the room control the 24,100-volt incoming lines from the generating station, 2650-volt single-phase and three-phase distributing circuits for light and power in Lucerne. The corresponding panel boards on the left-hand side of the room are for the control of 340-kw., 2650-volt, three-phase motors and 300-kw., 575-volt, direct-current generator and a number of tramway feeders. The oil circuit-breakers for the alternating-current circuit are located in concrete cells back of the panels, while the direct-current switchgear is arranged with the negative polarity on the main floor and the positive in the basement.

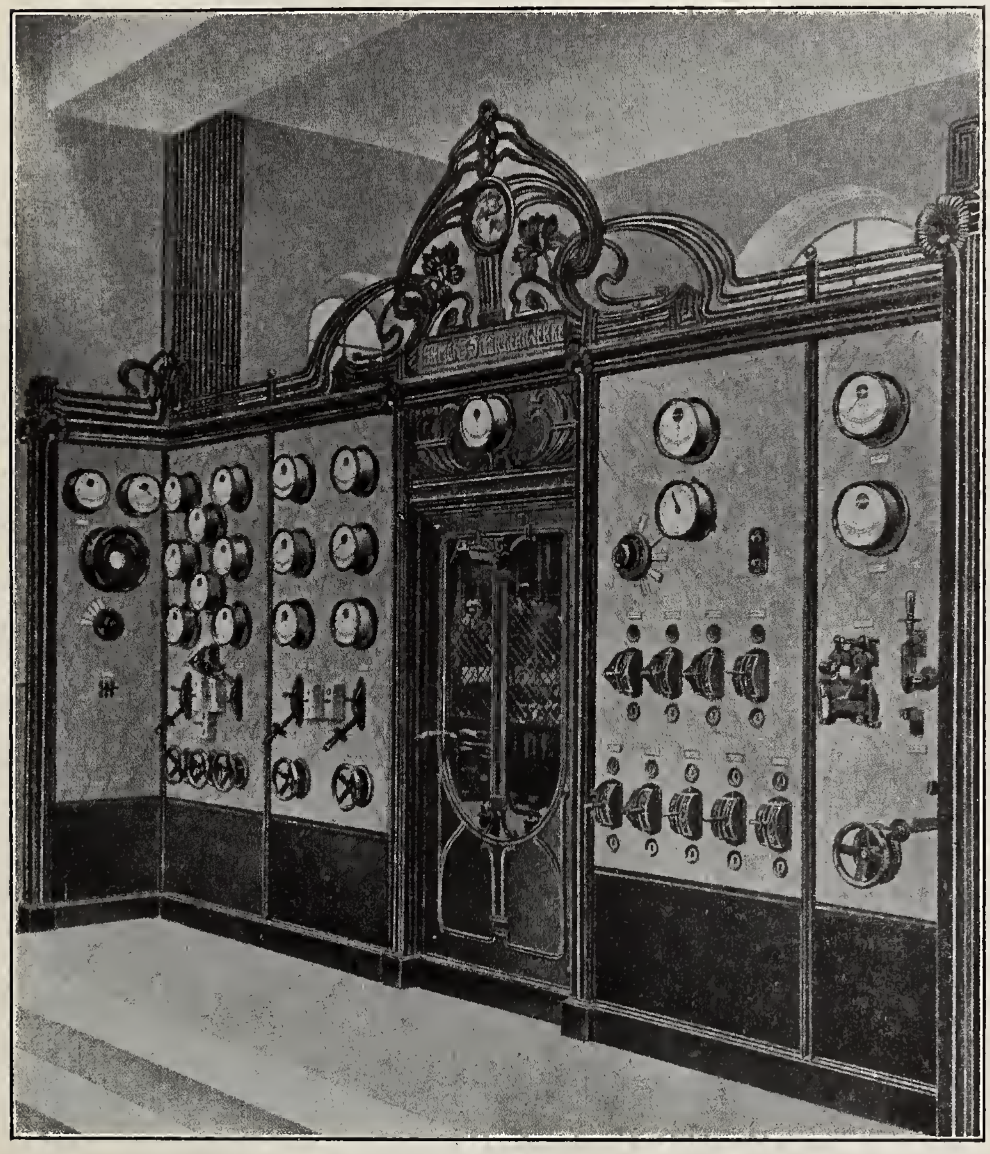


Fig. 7.—EUROPEAN (SIEMENS SCHUCKERT) PANEL BOARD, ELECTRICAL OPERATION, SCHWELM CENTRAL STATION

Fig. 7 shows a panel switchboard supplied by the Siemens Schuckert Works for the Schwelm central station for use with electrically operated oil circuit-breakers. As may be noted, the marble panels are set in a rather elaborate iron frame and the switchboard acts as a wall to the switchroom and is provided with a door in the center. The projecting panel at the left-hand end contains the station voltmeters and synchroscope. The second panel controls three generators, the third two generators and each generator circuit is provided with the usual meters, a push-button switch for circuit-breaker control, exciter rheostat, generator rheostat, etc. The first panel to the right of the door contains the operating switches and signal lamps for nine electrically controlled feeder-breakers. The remaining panels control various circuits. The rather elaborate iron framework is typical of German switchboard construction.

Section D—Cabinets of European design.

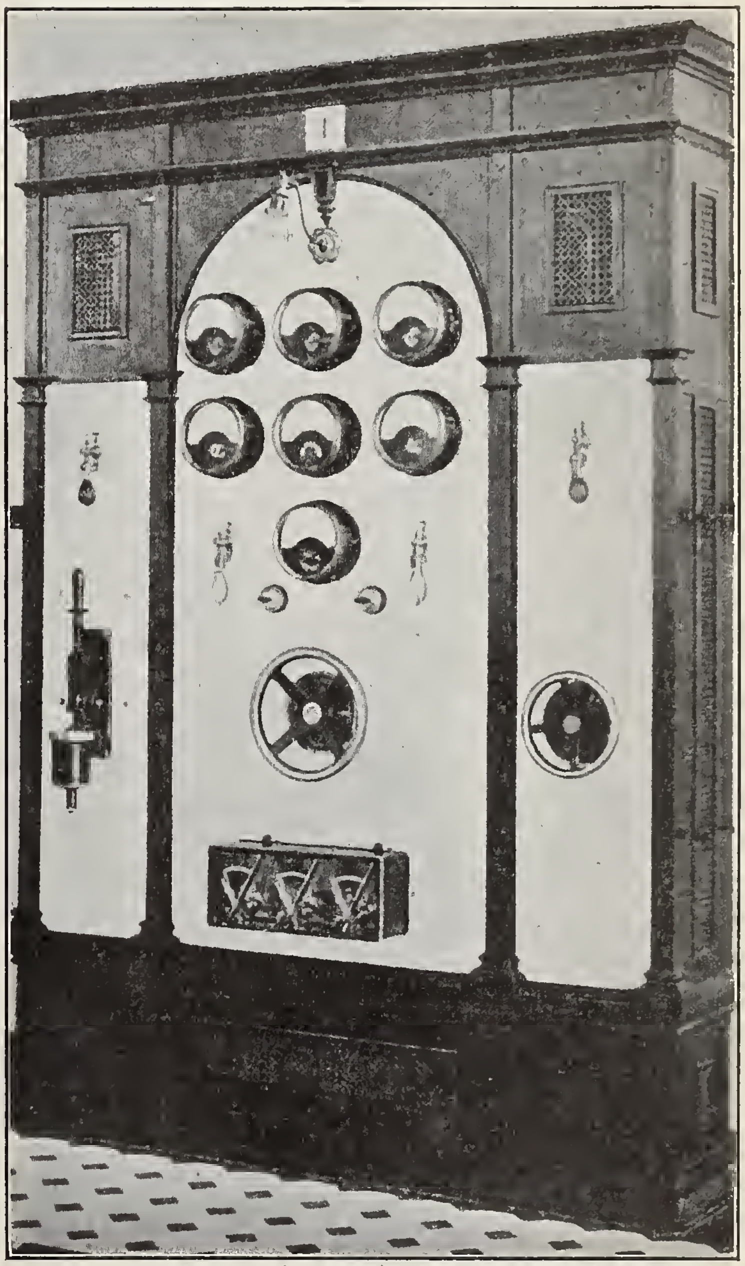


Fig. 8.—EUROPEAN (ALIOTH) CABINET, HAND OPERATION, CAMPOCOLOGNO STATION

Fig. 8 shows one of the control cabinets supplied by the Alioth Company for the Campo Cologno generating station in Switzerland used for the Brusio transmission in Italy. These cabinets, of which there are 12, are each used for the control of a 3000-k.v.a., 7000-volt generator and are placed along the wall of the station with their fronts in the generator-room and their rears in the bus-room. Each cabinet is provided with three ammeters, operated from series transformers, which also supply current to the three single-phase overload relays mounted on the lower part of the central panel. There are also three voltmeters, one for the machine, one for the bus and one for synchronizing. The remaining meter is a field ammeter. The operating handle on the left panel is used in connection with the field discharge switch inside the cabinet. The large hand-wheel on the central panel is used for the operation of the oil circuit-breaker, while the smaller hand-wheel on the right-hand panel is used for the field rheostat. The field switch, as well as the oil switch, is provided with a shunt trip actuated by the overload relay in such a manner that the overload in any one phase of the armature will open up the field circuit as well as the armature circuit. This opening up of the field circuit, due to an overload in the armature circuit, is a distinct departure from American practice, but is undoubtedly of value under certain unusual conditions, such as a short-circuit, either in the generattor or in the leads between the generator and oil switch. Under such conditions the current flowing from the bus bars to the short-circuit will actuate the overload relay and open the oil circuit-breaker to disconnect the bus from the short and open up the field circuit of the generator prac-

tically cutting off the generator from the trouble.

Fig. 9 shows one of the so-called wagon panels or cabinets installed by the Alioth Company in the feeder-house of the Montbovon (Switzerland) station of the Montreaux Oberland Bernois R. R. The front of the cabinet contains the instruments, relays, operating handle, etc., while the oil switch, series transformers and similar devices are closed in by a metal grillework and are only accessible from behind when the cabinet has been rolled out from the wall, automatically disconnecting the circuits from the bus bars.

Fig. 9.—EUROPEAN (ALIOTH) CABINET, HAND OPERATION, MONTBOVEN STATION

Section E—Cabinets of American design.

This type of construction is practically unused in American power plants, although occasionally a panel switchboard is used to form one wall of a room with its bus-bar switchgear, etc., in the second room. Sometimes a switchboard is closed in by metal grillework or two-panel switchboards are placed back to back with a space between to form a cubicle.

Fig. 10 shows such a cubicle furnished about 1898 by the Westinghouse E. & M. Company to the Glasgow Corporation Tramways for the control of 6600-volt feeder circuits. Manually operated carbon-break circuit-breakers were employed and were operated by a comparatively simple mechanism. These cubicles have lately been replaced by more modern appliances.

Section F—Pedestal Boards of American design.

When the Westinghouse E. & M. Company secured the contract for the first three 5000-h.p., 2200-volt, two-phase generators for Niagara Falls in 1893 their size far exceeded anything previously attempted, and the problem of switchgear involved a great deal of pioneer work. It was early realized that no switches then in existence could satisfactorily control these machines, nor was it considered feasible to attempt to operate by hand the switches that would have to be developed for this installation. Compressed air, which had been successfully used for many purposes, was finally settled on as being most suitable for the operation of the switchgear and its use led to the employment of the pedestal and post scheme of control for this installation.

Fig. 11 shows one of the control stands and instrument stands installed in 1895 and still in service in the No. 1 powerhouse of the Niagara Falls Power Company, where 10 of them are in use. The control stand, as may be noted, contains four valve handles, two for the compressed-air cylinders that operate the two main switches connecting the armature to either or both of two sets of bus bars, and two for the cylinders of the field switches. The hand-wheel is used for the rheostat control. On the instrument stand are placed two illuminating lamps, one round pattern field ammeter, two horizontal edgewise single-phase wattmeters, two ammeters and two voltmeters. Somewhat similar control and instrument pedestals were provided for the control of feeders, exciters, rotaries, etc. With the exception of the marble slabs for the instruments, the balance of the pedestals were metal.

Fig. 12 shows one of the control pedestals supplied in 1896 by the Westinghouse E. & M. Co. to the Consolidated Traction Company of Pittsburg for the control of 800-kw., direct-current railway generators. The switches and circuit-breakers were pneumatically operated, but owing to trouble with the air piping, this method of control has been abandoned in this plant, but these

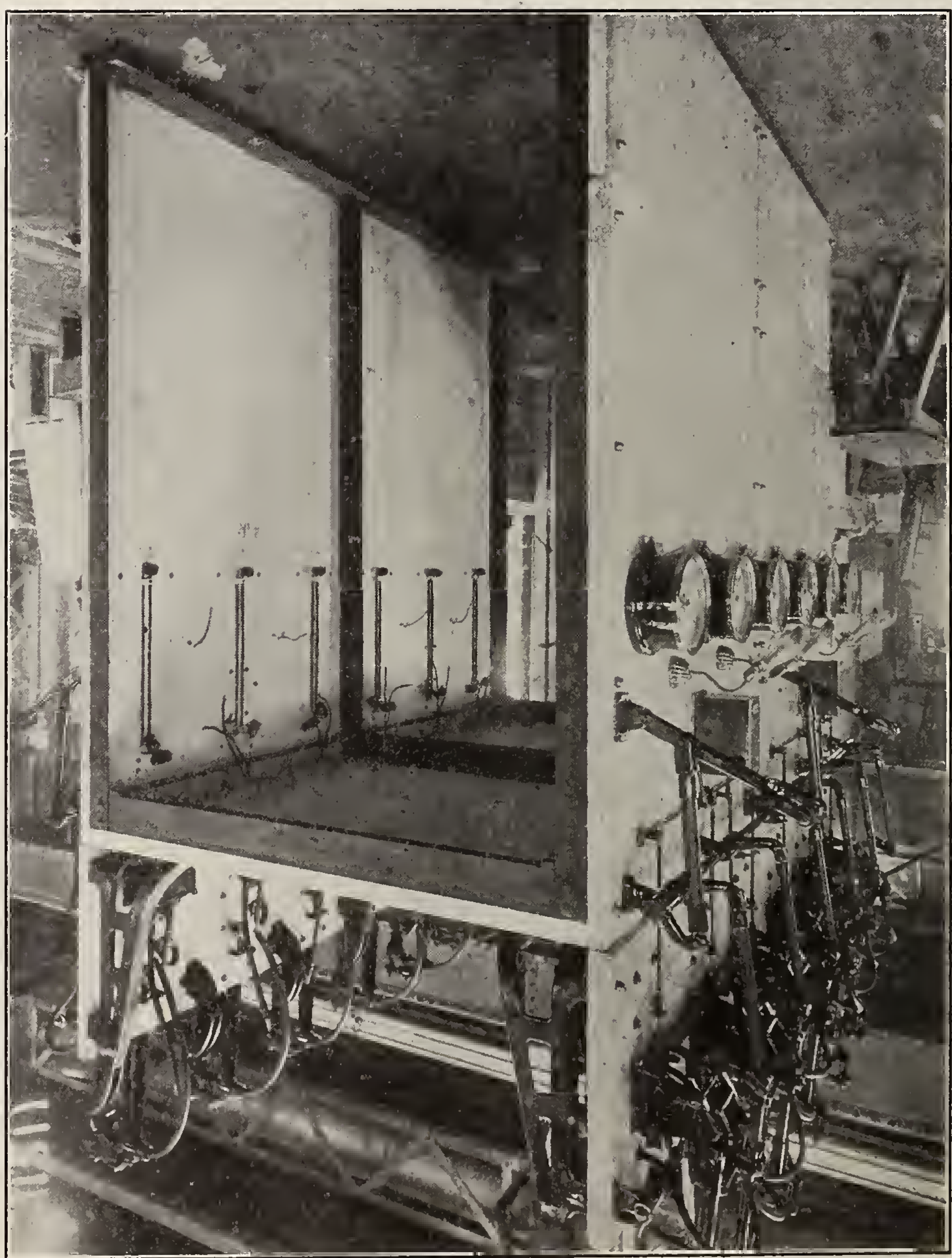


Fig. 10.—AMERICAN (WESTINGHOUSE) CUBICLE, GLASGOW CORPORATION TRAMWAY

pedestals are of interest from an historical point of view.

As the pneumatically operated devices were gradually superseded by electro-pneumatic control and these in turn by the straight-electric control, the pedestals and posts have been modified to correspond.

This pedestal type of control is ordinarily used in plants that distribute at the generator voltage and where the number of generators is small in comparison with the number of feeders.

Fig. 13 shows the arrangement of the switchboard gallery for the Union

Fig. 11.—AMERICAN (WESTINGHOUSE) CONTROL PEDESTAL AND POST, NIAGARA FALLS POWER COMPANY

Electric Light and Power Company of St. Louis for the control of eleven 6600-volt, 25-cycle, three-phase generators of various capacities and a large number of feeders. The generator controlling devices are located on a pedestal, while the generator instruments are placed on posts that act as supports for the gallery railing. A pivoted station post containing voltmeters, synchroscope, etc., is so located that the instruments can be observed from any portion of the gallery. With the arrangement shown, the operator on the switchboard gallery at the end of the station faces the generator-room when standing at the control pedestals and watching the generator instruments. The feeders are controlled from a panel board back of the operator, while the masonry structure for the bus bars and connections is back of the feeder board.

Fig. 14 shows the control-room in the distributing station of the Ontario Power Company at Niagara Falls, Ontario. Each of the four control pedestals and posts is used for the control of one 7500-kw. or 9000-kw., 12,000-volt,, 25-cycle, three-phase generator and one bank of three 3000-kw. transformers, stepping up to 60,000 volts. On these pedestals, in addition to the controllers and indicating lamps, a miniature bus-bar system has been installed to show just what connections have been made by the various breakers. The instrument posts contain the various meters for the generator and transformer circuits and are provided with testing jacks that permit the calibration of the instruments in position. The 60,000-volt feeder circuits running to Rochester, Syracuse and other points are controlled from the feeder panels shown on the right.

Fig. 15 shows the two galleries below the control-room illustrated in Fig. 14. The panels on the upper gallery contain complete sets of graphic recording instruments, integrating wattmeters, etc., while on the lower floor the panels contain the relays, fuse terminals, etc., in the various control and meter circuits.

It might be noticed that all of these examples of American pedestal construction are taken from the designs of one company—the Westinghouse E. & M. Company—as other companies developed their equipments more on the lines of control desks and bench boards during this same period.

Section G—Pedestal boards of European design.

In Europe the pedestal design has been adopted by a large number of manufacturers for the control of generators in plants of moderate size and these are ordinarily used with manually operated switching gear.

Fig. 16 shows the equipment installed by the Oerlikon Company in the generating station of the Engelberg Lucerne Power transmission for the control of 1850-k.v.a, 6000-volt, three-phase generators. The generator pedestals on the right of the cut contain a single-phase wattmeter with Y box, an alternating-current ammeter, a double scale voltmeter with one scale indicating the generator voltage and the other used as a phase voltmeter for synchronizing. The pedestal is also provided with levers to operate oil circuit-breakers, switches for light and power, rheostat hand-wheels and the carbon-breakers in the field circuits.

A very ingenuous arrangement of

Fig. 12.—AMERICAN (WESTINGHOUSE) CONTROL PEDESTAL AND POST, PITTSBURG RAILWAY COMPANY

the levers makes it necessary for the attendant to perform his various operations in proper sequence. The oil-breakers cannot be closed if the field switch is opened, and conversely unless the oil circuit-breaker is open the field switch cannot be opened nor the bus knife switches manipulated. The switches, hand-wheels for exciter and generator rheostats, receptacles, signals, push-button control switches, etc. Bus instruments are mounted on pivoted brackets attached to the columns of the gallery and graphic recording instruments are placed on the same columns. Electrically operated

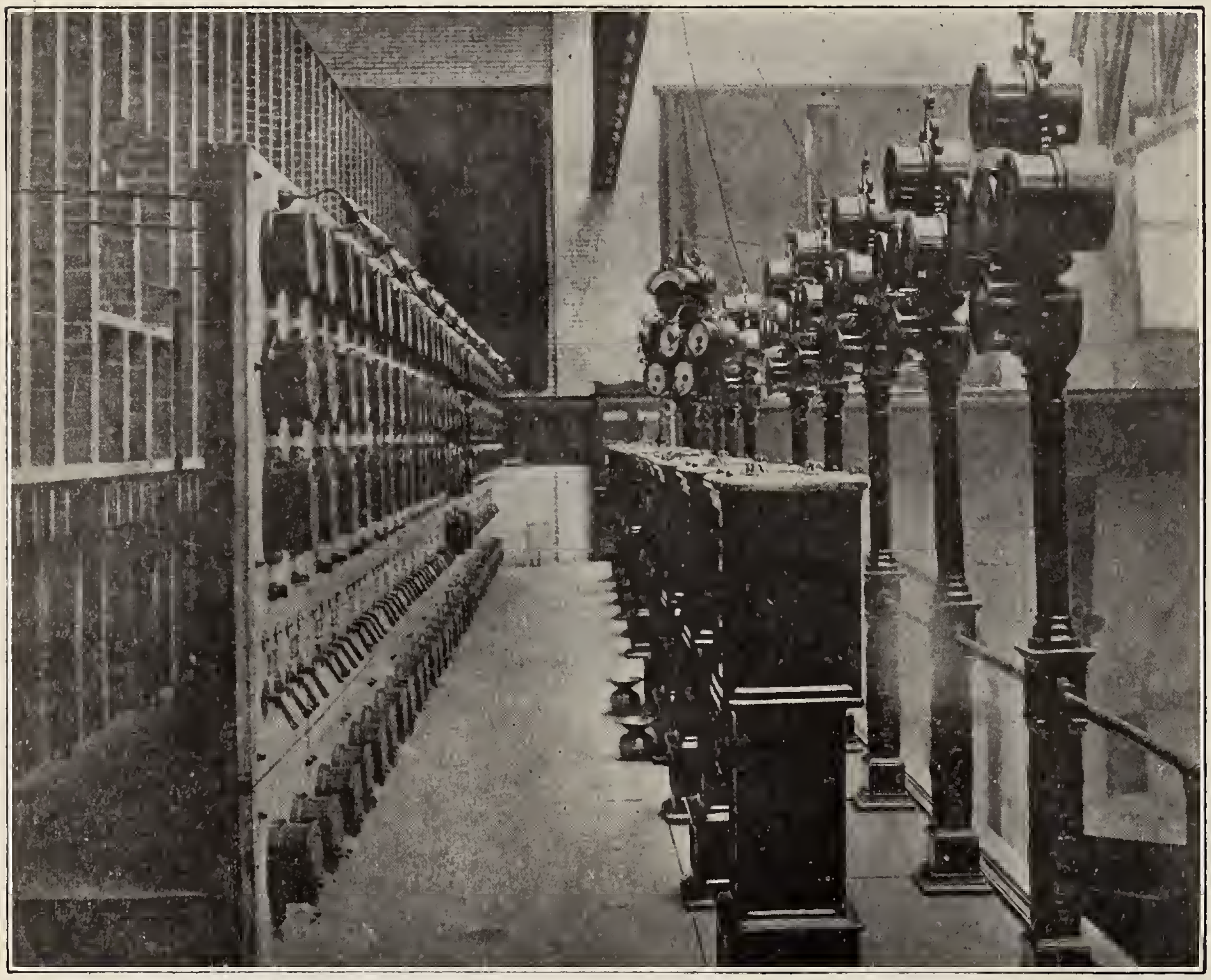


Fig. 13.—AMERICAN (WESTINGHOUSE) CONTROL PEDESTAL AND POSTS, UNION ELECTRIC LIGHT & POWER COMPANY, ST. LOUIS

voltmeter and wattmeter are automatically connected by the movement of the operating lever in such a way as to give proper indication without any further trouble. A white lamp lights up when the breaker is closed and a red one when open. An acoustic signal operates on the opening of a breaker, but this can be cut out immediately by hand if desired.

The battery control pedestal in this plant carries two ammeters, a voltmeter switch, handles for two breakers, as well as for the end cell switches and two control indicators. The exciter pedestals each contain a voltmeter, ammeter, field rheostat, hand-wheel and two interlocked levers to work the switch and circuit-breaker. Sectionalizing switches in the main bus bars are operated from this control platform.

Fig. 17 shows the combination pedestals and posts supplied by the Siemens Schuckert Works in the Altona (Germany) plant for the control of steam turbo-generators. Each main post is provided with round pattern instruments, comprising a field ammeter, main ammeter, voltmeter and wattmeter with the necessary control oil switches are controlled from these pedestals.

Section H—Desk switchboards of European design.

Most of the control desk switchboards used in Europe are made with cast-iron tops with the instruments set in the tops and sheet metal sides, and are arranged for manual or electrical control of the oil circuit-breakers and similar devices.

Fig. 18 shows a control desk made by the Siemens & Halske Company with vertical edgewise and round pattern instruments set in the top of the desk. The large hand-wheel on the front of the desk is used for the manually operated oil circuit-breaker, while the overload time limit relay is set in the front of the desk and is provided with a glass cover. The two large segmental devices in the top panel at the right- and left-hand side of each section are the field rheostat devices for the generators and the direct-connected exciters. The six smaller devices are signal switches. The embossed sheet iron forming the front and ends of the desk makes a cheap and satisfactory arrangement.

Fig. 19 shows a control desk made by the Brown Boveri Company and installed in the Castellanza (Italy) station for the control of a 7500-h.p., 11,000-volt turbo-generator. This pedestal is provided with a cast-iron top, in the face of which are mounted flush type round pattern instruments, synchronizing lamps and similar devices. Back of the pedestal is placed a combination instrument, comprising a poly-phase indicating wattmeter reading up to 8000 kw., a voltmeter and an ammeter. The oil circuit-breaker for the generator is located in the basement and is operated by means of a hand-wheel and sprocket mechanism, while the generator rheostat is controlled by a similar hand-wheel and sprocket mechanism. The front sides and back of this control pedestal are made of perforated sheet

Fig. 14.—AMERICAN (WESTINGHOUSE) CONTROL PEDESTALS AND POSTS, ONTARIO POWER COMPANY, NIAGARA FALLS

Section I—Desk boards of American design.

Fig. 15.—AMERICAN (WESTINGHOUSE) PANELS USED WITH PEDESTALS, ONTARIO POWER COMPANY, NIAGARA FALLS

Fig. 20 is a compromise between the pedestal and control desk type of construction of comparatively early date. This cut shows the gallery with generator stands and instrument panels installed in 1901 at the Third Avenue powerhouse of the Brooklyn Heights Railway Company for the control of six 2700-kw., 6600-volt, three-phase generators. The general arrangement is such that the station attendant while standing at the generator pedestal or desk can readily look under the instrument panels and watch the machines he is controlling. Each desk consists essentially of a cast-iron frame with rectangular marble slabs arranged to form the front, back and top, while circular slabs on the sides act as supports for the hand-wheel, the reverse current relay, knife switches, etc.

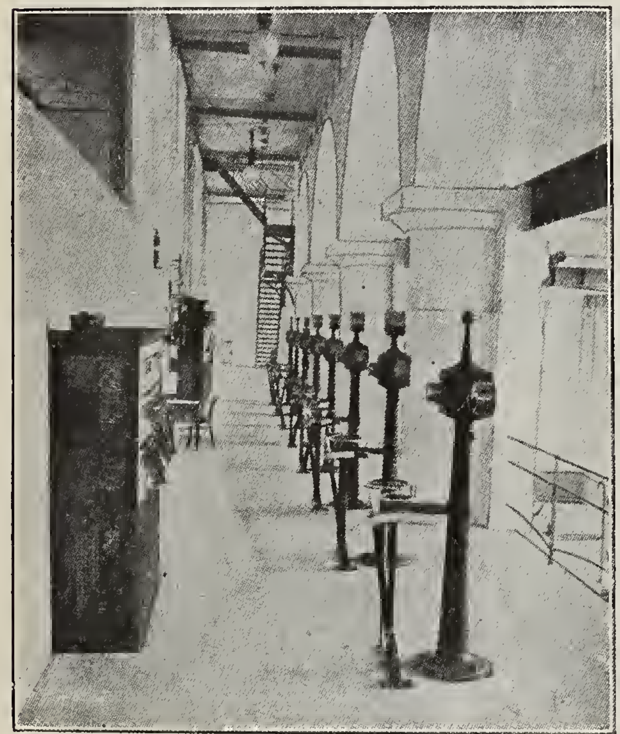


Fig. 16.—EUROPEAN (OERLIKON) CONTROL PEDESTALS, ENGELBERG LUCERNE PLANT

The feeder panels are located on the same gallery as the generator desks and a short distance back of them with an aisle between to allow space for the operator. Each feeder panel controls two feeders and is provided with proper meters, relays, controllers, indicators, etc.

The generator field rheostat is operated by means of a large hand-wheel on the right-hand side of each desk, connected by bevel gear with a face-plate mounted underneath the resistance grids that are located on the switchboard gallery back of the feeder panels.

Each generator desk has a two-pole hand-operated field switch with discharge resistance on the vertical front slab. The diagonal front slab is provided with three circuit-breaker controllers with electro-mechanical tell-tale devices. The top slab is provided with indicating and synchronizing lamps of the bull's-eye pattern, a synchronizing receptacle and a three-pole, double-throw switch for the control of the speed governor motor.

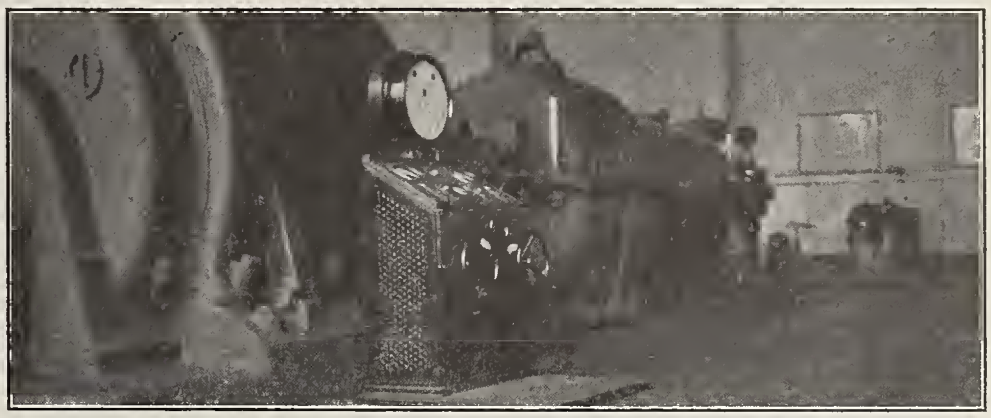


Fig. 19.—EUROPEAN (BROWN BOVERI) CONTROL DESK, CASTELLANZA PLANT

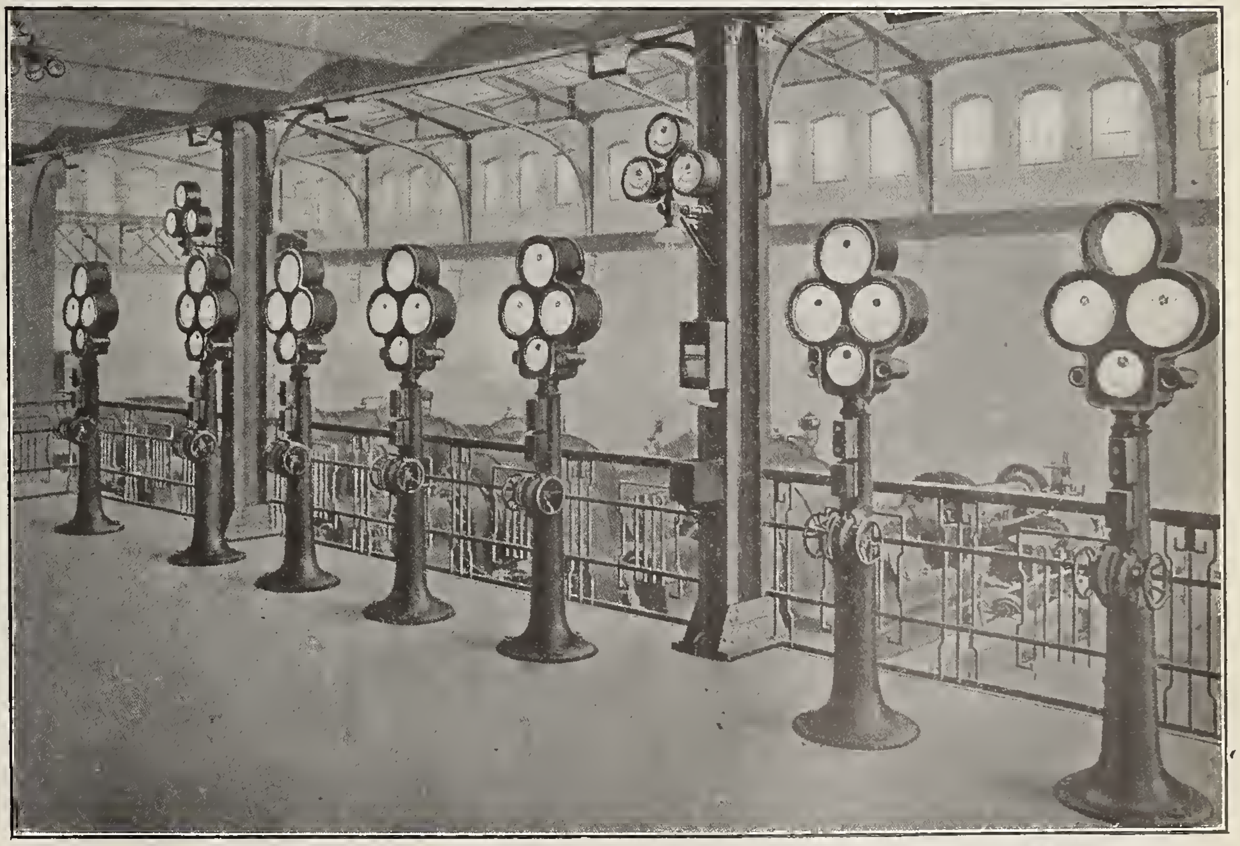


Fig. 17.—EUROPEAN (SIEMENS HALSKE) CONTROL PEDESTALS, ALTONA PLANT

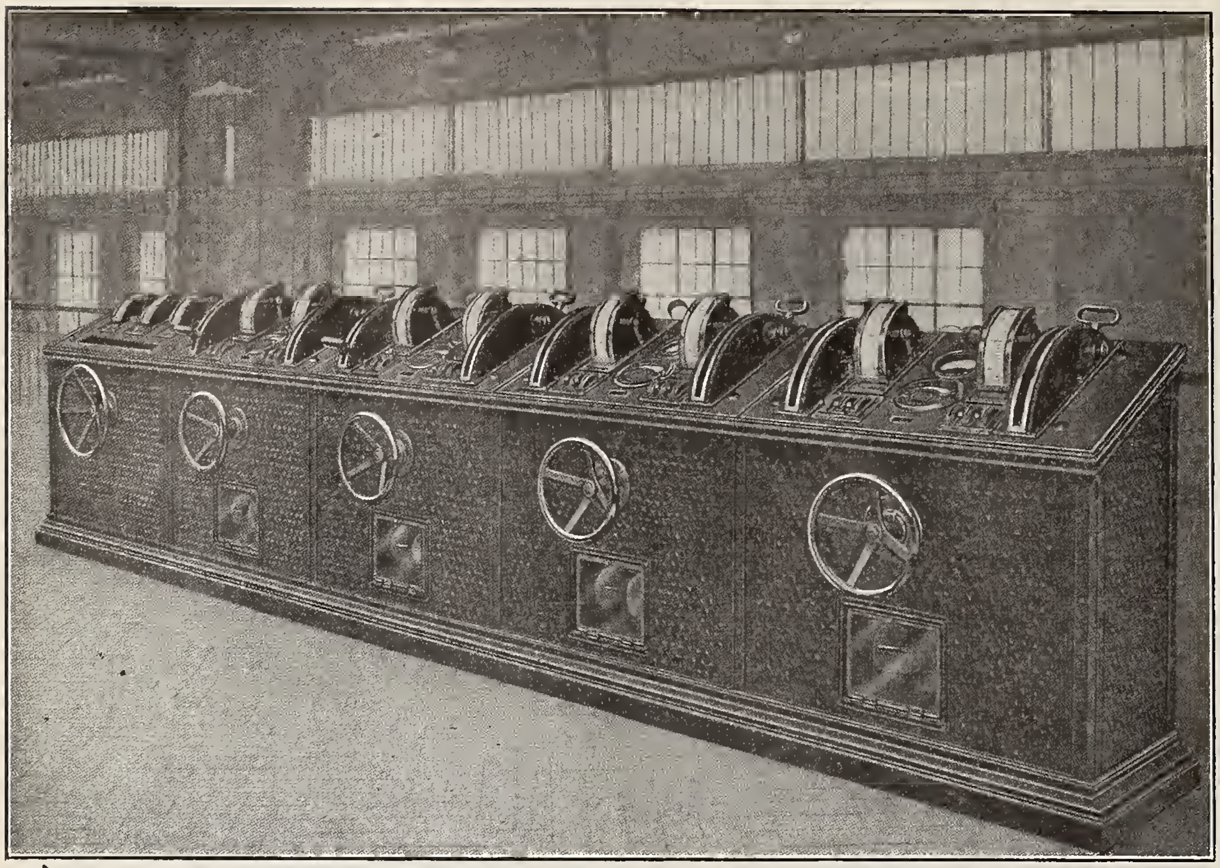


Fig. 18.—EUROPEAN (SIEMENS HALSKE) CONTROL DESK

The diagonal back slab is provided with three small fused knife switches, while the vertical back slab is blank.

In front of and above each generator desk is an instrument panel containing a field ammeter, three alternating-current ammeters, a generator voltmeter, poly-phase indicating wattmeter, power-factor meter, poly-phase integrating wattmeter, synchroscope, synchronizing lamps and signal device.

With later American control desks where it is desired to reduce the length of the operating board to a minimum it is customary to install a continuous control desk and to mount on it the various controllers for the circuit-breakers, field switches, field rheostats, etc. It is customary to mount the instruments for the various circuits in such a position relative to the sections of the desk as to indicate clearly to the station operator the instruments belonging to any particular circuit.

With the control desk the instruments can be mounted either on independent switchboard panels, or on panels forming the back of the control desk, or on an instrument frame back of and usually higher than the top of the control desk or on instrument posts.

Where panels are used with a control desk, ordinarily the panels occupy a greater amount of space than the desk and it is possible for the station operator to become confused in determining the instruments belonging with a certain generator or feeder whose controlling devices are on the desk. As a rule, card-holders or name-plates are placed both on the desk and the panels, and the grouping of the instruments is made as far as possible to correspond with the grouping of the controlling devices.

Where instrument panels form the back of the control desk, the instruments are, as a rule, arranged to correspond in location with the controlling devices for the same circuits.

A modification of this scheme is to use an independent instrument frame and to arrange this frame at such a height that the station operator standing at the control desk can look over the top of the desk and under the bottom of the instrument frame out into the station and readily observe the operation of the machine he expects to control.

Fig. 21 shows a control desk of the first type, namely, for use with independent instrument panels that was supplied by the Westinghouse E. & M. Co. to the Provincial L. H. & P. Co., of Montreal, for the control of five 3750-k.v.a., 4400-volt, three-phase generators with provision for a sixth generator, two banks each of 3-3750-k.v.a., 4400/44,000-volt step-up transformers, two 44,000-volt feeder

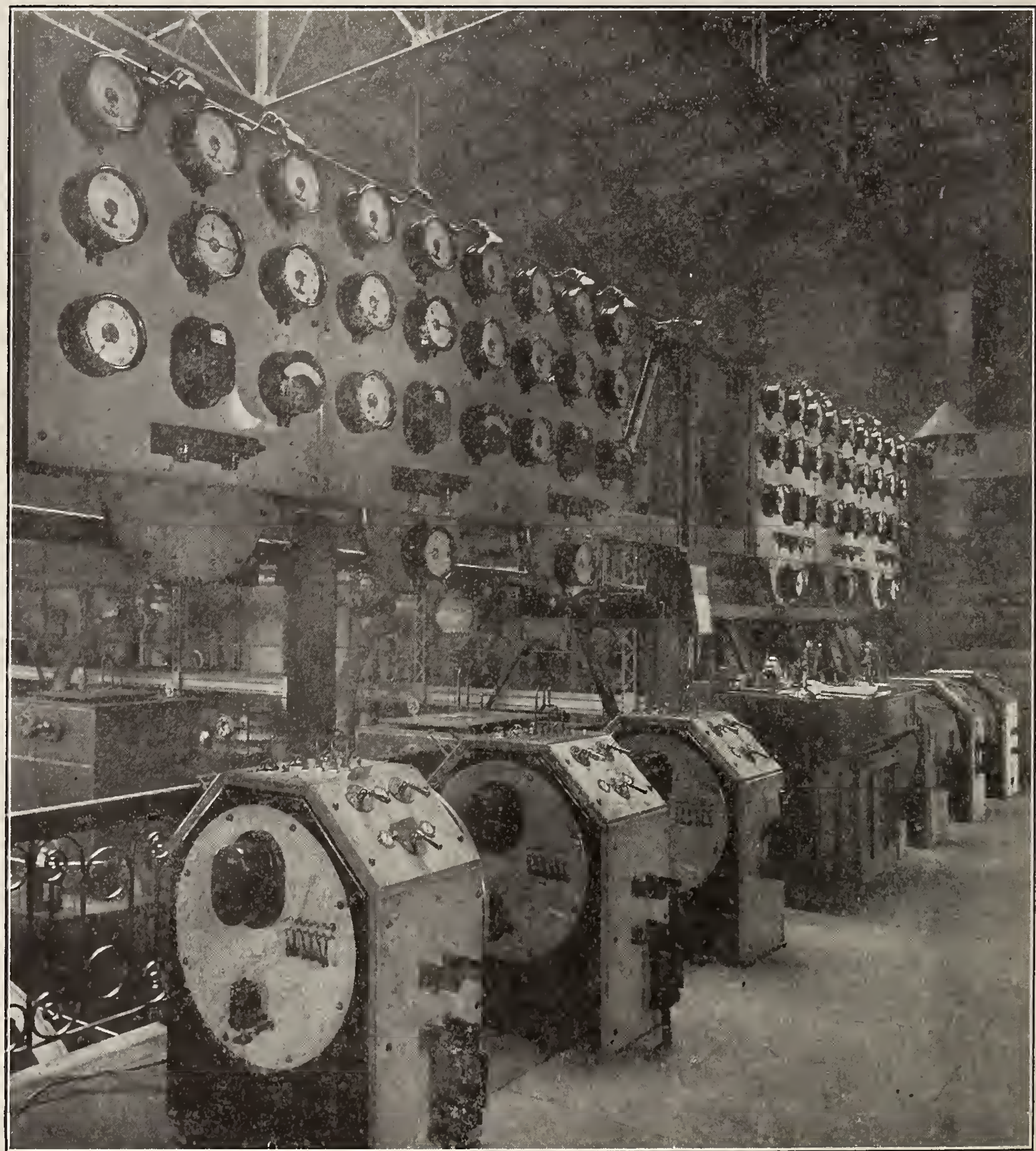


Fig. 20.—AMERICAN (WESTINGHOUSE) CONTROL DESK, BROOKLYN HEIGHTS R. R.

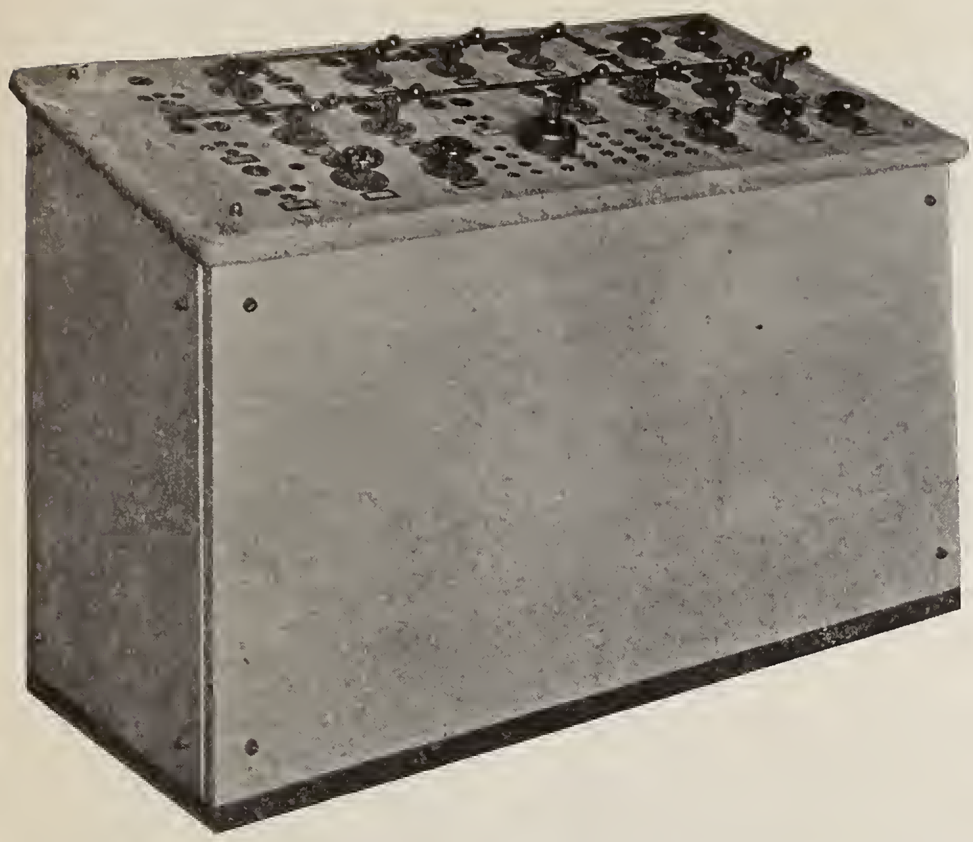


Fig. 21.—AMERICAN (W. E. & M. CO.) CONTROL DESK, PROVINCIAL LIGHT, HEAT & POWER CO.

Fig. 23.—AMERICAN (W. E. & M. CO.) CONTROL DESK, CARNEGIE STEEL CO.

Fig. 22.—AMERICAN (G. E. CO.) CONTROL DESK, N. Y. C. & H. R. R. R.

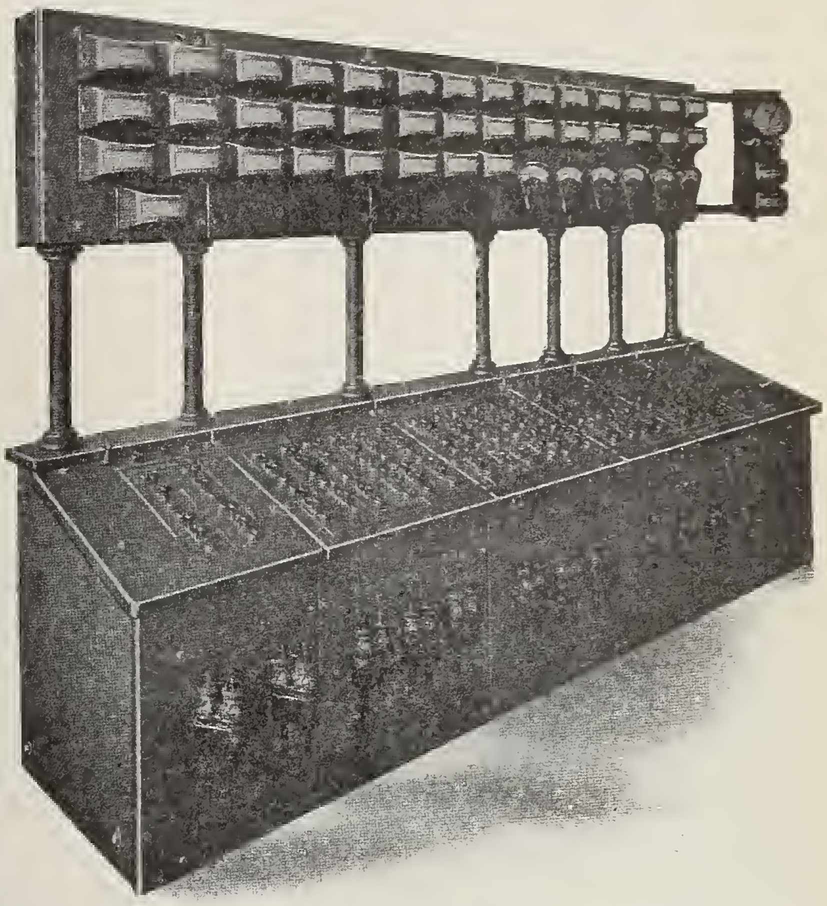


Fig. 24.—AMERICAN (G. E. CO.) CONTROL DESK, SALT RIVER PLANT

circuits and one 4400-volt feeder circuit with provision for a second 4400-volt feeder. This control desk had a top slab 32 in. wide, 65 in. long and was provided with a miniature bus-bar system, which, taken in conjunction with the red indicating lamps, shows at a glance the connections made by the various breakers controlled from the desk. The instruments for the various circuits were mounted on standard size panels which were placed at a short distance in front of the desk.

Fig. 22 shows a control desk of oil-finished slate with horizontal edgewise instruments on panels forming the back of the desk installed by the General Electric Co. in the Port Morris generating station of the New York Central & H. R. R. for the control of six 5000-kw., 11,000-volt, three-phase generators, with various feeders. With this type of desk the station operator has his back toward the generator-room, which is usually an objection to this arrangement.

Fig. 25.—AMERICAN (W. E. & M. CO.) CONTROL DESK, UNITED RAILWAYS & ELECTRIC COMPANY, BALTIMORE

Fig. 23 shows a control desk with blue Vermont marble top and steel plates for the front and sides supplied by the Westinghouse E. & M. Co. to the Carnegie Steel Company at Youngstown. The round pattern meters are mounted on separate panels located back of and above the desk at such a height that the operator can look over the desk and under the instrument frame to observe the operation of the generators. This desk controls four 2000-kw. and one 1000-kw., 6600-volt generators, two synchronous motors and four high-tension feeders and is provided with a miniature bus. Hand-operated field switches are used for the generators, while the field rheostats and oil circuit-breakers are electrically operated. The total length of the board is only 11 ft. and makes a very compact arrangement. The leads to the instruments are run through the hollow cast-iron columns that support the frame.

Fig. 24 shows a control desk supplied by the General Electric Company to the United States Reclamation Service, Salt River Project, for the control of six 1060-k.v.a., 25-cycle, three-phase generators, 2300 volt; six three-phase banks of transformers 2300/44,000 volts and two 6000-kw., 44,000-volt, three-phase outgoing lines. There is a complete double-throw equipment both for the 2300-volt circuits and the 44,000 volt. A complete miniature bus system is located on the top of the desk and is used with the signal lights and operating switches to show the main connections of the plant.

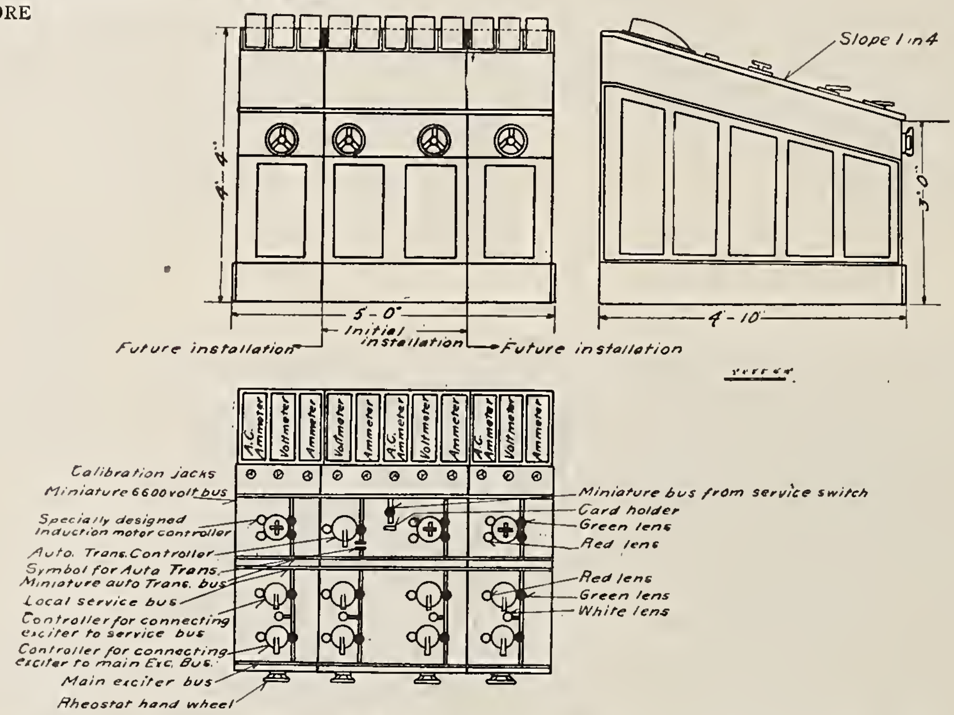


Fig. 26.—AMERICAN (W. E. & M. CO.) CONTROL DESK, WINNIPEG EXCITERS

This desk is made up of six sections of oiled black slate with a total height, including the instrument frame, of 98 in. and a total length, exclusive of the swinging panel, of 151 in. The swinging panel at the right-hand end contains two voltmeters, a synchroscope and two synchronizing lamps. The three sections at the right-hand end each control two generators, the next two sections each control three banks of transformers and the section at the extreme left controls the two transmission lines.

Fig. 25 shows a control desk with vertical edgewise instruments supplied by the Westinghouse E. & M. Co. to the United Railways & Electric Company, of Baltimore. This desk was arranged to form an arc of a circle and will ultimately be about twice as large as the portion shown. A complete miniature bus-bar system is installed on the top of the desk to

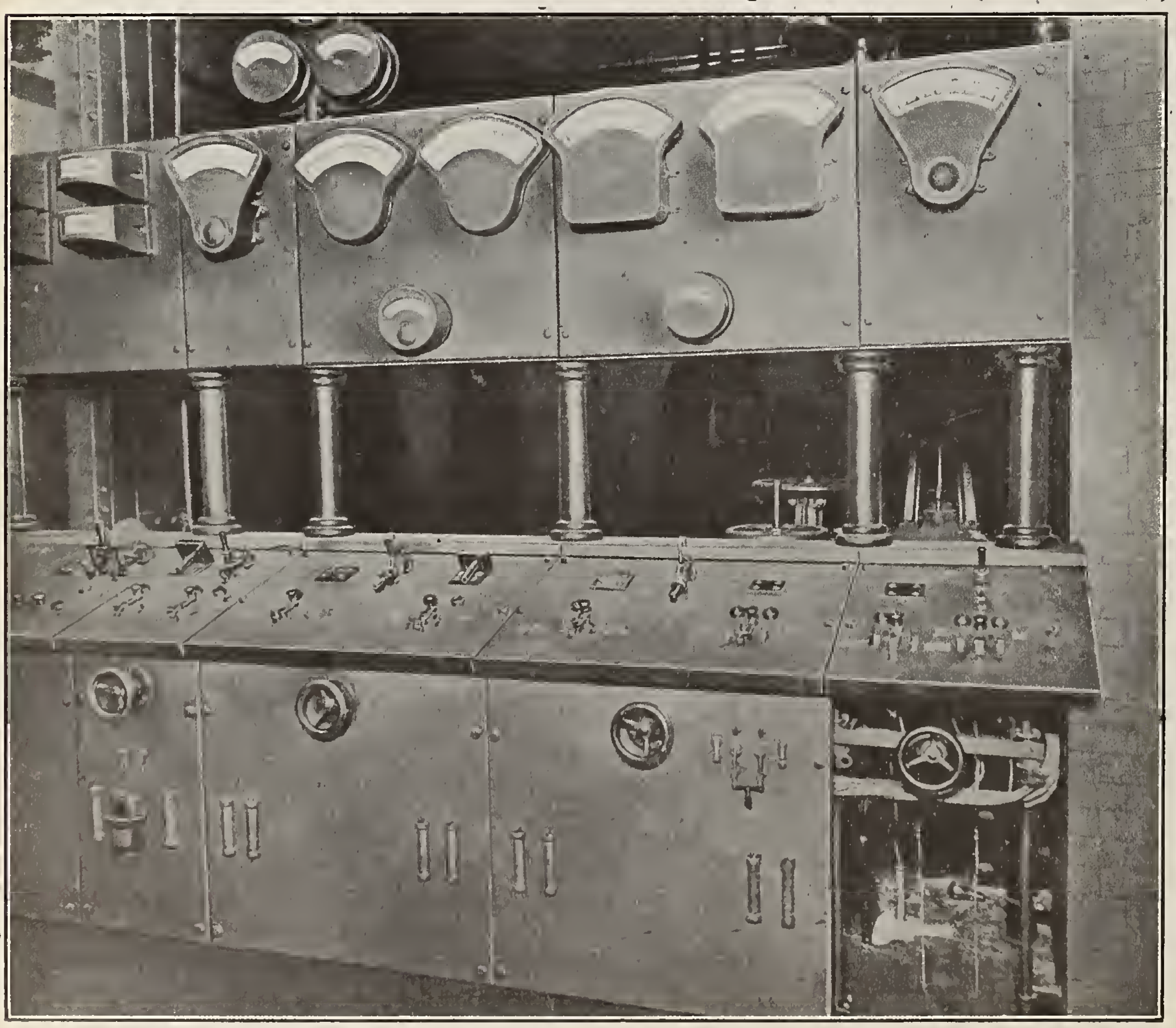


Fig. 27.—AMERICAN (WESTERN ELECTRIC) CONTROL DESK, INDIANA STEEL COMPANY

show the connections made by the various breakers that are arranged on the group and ring system. Calibrating jacks are installed on the front panels of the desk to permit any of the switchboard instruments to be calibrated in position. The meters are mounted on steel plate and the relays are located on the rear of the desk.

Fig. 26 shows a control desk with vertical edgewise instruments arranged in the face of the desk in such a manner that the operator can readily look over the top of the desk to watch the generating station which he will face when standing at the desk.

This desk, proposed by the Westinghouse E. & M. Co. for the City of Winnipeg, was intended for the control of three motor-driven exciters and one water-wheel-driven machine, and is provided with a miniature bus showing the connections made by the breakers in the different circuits. The actual design of this desk will be somewhat modified from the arrangement shown.

Fig. 27 shows a portion of the control desk supplied by the Western Electric Company to the Indiana Steel Co. for the control of some of the direct-current circuits in that plant. This desk is provided with an instrument frame mounted on hollow columns through which the leads pass to the meters. These examples of switchboards, pedestals, desks, etc., give a fairly comprehensive view of the development and present tendency in their design. It has been, of course, impossible to take up all of the intermediate steps in their gradual evolution and equally impossible to describe and illustrate the latest designs of all manufacturers.

The distant control apparatus used in connection with these switchboards, as well as the arrangement of typical power plants containing these equipments, will form the subject of future articles.

[*To be continued.*]

The Equipment and Working Results of the Mersey Railway under Steam and under Electric Traction

By JOSHUA SHAW, M. Inst., C.E.

During recent years one of the problems which has had to be considered by both railway and electrical engineers, has been the substitution of the electrical system of traction on existing railways hitherto worked by steam. Up to the present the number of railways in England in which this substitution has been made is very limited, and consequently little is generally known as to what the actual effect of the change has been on the working results. In this paper the author presents some comparisons of the equipment and working results of the Mersey Railway when operated first by steam and later by electricity.*

THE MERSEY RAILWAY

The railway, extending under the River Mersey, connects Liverpool and Birkenhead on opposite banks. A map of the line and the district which it serves is given in Fig. 1.

The original route extended from James Street station, Liverpool, to Green Lane station, Birkenhead, a length of 2 miles 11 chains; but extensions have since been made, increasing the total length to 4 miles 62 chains. The railway commences under the terminal station of the Cheshire Lines Committee in Liverpool and runs under the River Mersey to Rock Ferry, where a junction is made with the London and North Western and Great Western Joint Railway. From Hamilton Square station a branch line runs to Birkenhead Park station and connects there with the Wirral Railway, which runs to New Brighton and West Kirby.

All the stations are below the street level at the depths given in Table I:

TABLE I.

		Feet
Central Station, Liverpool		30
James Street,	"	89
Hamilton Square	Birkenhead	100
Central Station,	"	20
Green Lane,	"	25
Rock Ferry,	"	20
Park,	"	25

The two deep-level stations, James Street and Hamilton Square, are provided with hydraulic passenger lifts, the remainder having stairways only.

One large tunnel, 19 ft. high and 26 ft. wide, takes both lines of rails. The two deep-level stations are 30 ft. high and 50 ft. 6 in. wide. Under the main tunnel in the river section is a heading ranging from 7 to 8 ft. in diameter, for dealing with the drainage-water; and at the side of the main tunnel another heading, 7 ft. in diameter, was constructed for ventilation purposes.

Under the original conditions the railway had many features prejudicial to the commercial success of the undertaking, some of which were:

The steep gradients, necessitating the use of exceptionally heavy locomotives. A section of the gradients is shown in Fig. 2.

The difficulty and cost of efficient ventilation.

The necessity for continuous pumping.

The necessity for maintaining a lift service at two of the stations.

These items caused the working expenses to be extremely heavy, and the difficulty of maintaining efficient ventilation had a very serious effect on the revenue of the Company, causing many of the cross-river passengers to leave the railway and use the ferry service, which is maintained by the Birkenhead Corporation.

The steadily decreasing traffic (indicated at the beginning of Fig. 3) made it quite evident that some radical change would have to be carried out in order to recover the traffic which was being driven away. The question of adopting a different form of traction was under consideration for many years, the only schemes which could be considered being the electric and cable systems; and finally in 1900 the Company obtained parliamentary powers to work the railway by electricity. In the following year a contract was entered into for the conversion of the line, and the work was commenced in December, 1901, electric working being inaugurated on the 3d May, 1903.

When the electrical works were available, the question as to the best method of making the actual change from steam to electric working was carefully considered, and it was finally decided that it would be much more satisfactory to have a complete and rapid change than to bring the new service into operation gradually and run a mixed service of steam and electric trains during the transition stage. The last steam train left Liverpool at 12.15 A. M. (at its ordinary time) on the morning of Sunday the 3d May, and at 6 A. M. the same morning the three-minutes' service of electric trains was inaugurated. It was run light until 1 P. M., when the railway was opened to the public at the usual time.

*Inst. of Elec. Eng.

ELECTRICAL EQUIPMENT AND WORKING

Rolling Stock and Train Service.—The traffic conditions of the railway call for a service from 4.45 A. M. to 12.15 A. M., a total of 19½ hr. per day. The peaks of the traffic occur between 7.30 and 10.30 A. M. from Birkenhead to Liverpool, and between 4.30 and 7.30 P. M. in the reverse direction.

During steam working the trains consisted normally of seven 4-wheeled coaches hauled by a 66-ton locomotive, the number of trains per hour being varied to meet the traffic requirements.

During electric working the interval between trains remains constant throughout the day, the peaks of the traffic being met by increasing the number of coaches per train. The interval is 3 min. through the river section with alternate trains running to Park and Rock Ferry, thus forming a 6-min. service on each of these routes.

The train service commences in the morning with two-car trains and is increased to five-car trains about 7.30 A.M. for the heavy traffic at morning, after which it is reduced again to two cars until the evening heavy service. The time allowed at the terminal stations is 3 min., and the building up and reducing of the trains has to be carried out within this time. The average time taken is about 2 minutes per train, which includes shunting and the coupling up of brake and electrical connections. There are 374 trains each way per day, a total of 748, out of which 114 make connections with steam trains at Rock Ferry, and 117 with steam trains at Park, the remaining 517 being purely local.

The electric rolling stock provided for working the service consists of 24 motor-cars and 33 trailer cars, as described in detail in Table II.

TABLE II.

	Number of Cars.	Class.	Weight.	Number of Seats.	Weight per Seat.	Seats per Ton.
			Tons.		Cwt.	
Motor-cars	12	First	36¾	46	15.9	1.25
" "	12	Third	36¾	50	14.7	1.36
Trailer-cars	11	First	19¾	56	7.05	2.83
" "	17	Third	19¾	64	6.1	3.24
" "	5	Compo.	19¾	60	6.6	3.03

In the following table the two-train services are compared as regards the number of trains, mileage and seating capacity:

TABLE III.—WEIGHTS OF TRAINS, MILEAGE AND SEATING CAPACITY.

	Light Traffic. Steam.	Light Traffic. Electric.	Heavy Traffic. Steam.	Heavy Traffic. Electric.
Weight of train (unloaded) Tons	137¾	56½	137¾	122½
Number of seats per train	310	110	310	250
Weight per seat Cwt.	8.9	10.25	8.9	9.8
Number of trains per hour	8	20	12	20
Train-miles " "	50.7	127.2	78.3	127.2
Ton-miles " "	6,984	7,186	10,785	15,582
Seat-miles " "	15,717	13,992	24,273	31,800

Not only has the frequency of the service been greatly improved, but the speed of the trains has been increased and the length of time taken for the journey is reduced. This is shown in Table IV.

During heavy traffic in steam working several trains were run to and from Rock Ferry as expresses, without stopping at Hamilton Square and Green Lane, which enabled them to accomplish the journey in the same time as is now taken by the electric trains when stopping at every station.

TABLE IV.—RUNNING-TIMES AND AVERAGE SPEEDS WITH STEAM AND ELECTRIC TRACTION

Stations.	Distance between Stations.	Steam. Running-Times.	Steam. Speed.	Electric. Running-Times.	Electric. Speed.
	Chains.	Mins.	Miles per hour.	Mins.	Miles per hour
Liverpool Central and James Street	44	2¼	14.6	1¾	18.8
James Street and Hamilton Square	94	3½	20.1	2½	28.2
Hamilton Square and Birkenhead Central	42	2½	12.6	1¾	18
Birkenhead Central and Green Lane	35	1½	17.5	1½	17.5
Green Lane and Rock Ferry	60	2¾	16.3	2¼	20
Total time and average speed for main line, excluding stops	275	12½	16.5	9¾	21.1
Hamilton Square and Park (branch-line)	97	3¼	22.4	3¼	22.4
Average speed for whole railway, excluding stops	..	..	17.7	..	22.2
Average speed for whole railway, including stops	..	..	15.6	..	19.9

Increase in average speed, including stops, 4.3 miles per hour.
Decrease in running-time required for single journey:—
Central Station to Rock Ferry = 2¾ minutes.
Central Station to Park = 1 "

Table V gives the comparative seating capacity and weights for the total quantity of rolling stock required in the working of the steam and electric service respectively.

TABLE V.

	Steam.	Electric.
Stock	Locomotives 18; Coaches 96	Motor-cars 24; Trailers 33
Total seats	4,280	3,156
Total weight of stock Tons	2,172	1,534

The greatly improved distribution of the weight in the electric trains is shown in Fig. 4, from which it will be seen that the maximum weight that could be concentrated on any single rail (30 ft.) is only 15.89 tons (including 1.77 tons for passengers) as against 33 tons with steam traction.

The longitudinal seats provided in the electric cars allow more floor space per seat than in the compartment type of the steam stock, and the floor space provided per seat is shown in Table VI.

The electric rolling stock is of the corridor type. Each car is 60 ft. long over buffers, the motor-cars having a motorman's compartment 4 ft. long at one end and behind this a baggage compartment 10 ft. long, the remainder of the car being divided into two compartments (smoking and non-smoking). The maximum width of any car is 8 ft. 8½ in., the length between the centers 44 ft., the wheel-base of the motor 6 ft. and that of the trailer 5 ft. 6 in.

The cars are provided with automatic center-couplers and center-buffers, and the passenger platforms are fitted with gates operated by the Gould locking apparatus. Between each pair of cars the following couplings are provided: A seven-core cable for Westinghouse electro-pneumatic control, the positive and negative lighting cables and the Westinghouse air-brake pipes.

TABLE VI.—FLOOR-SPACE ALLOWED PER SEAT.

	Steam. Square Feet.		Electric. Square Feet.
First-class	4.8	Motor	6.3
		Trailer	6.28
		Average	6.29
Third-class	3.6	Motor	5.8
		Trailer	5.5
		Average	5.65

The increase in space per seat is 1.49 square foot in first-class and 2.05 square feet in third-class cars

The trucks are of the Baldwin type, having wheels 33 in. in diameter on the motor-cars and 30 in. in diameter on the trailer cars.

Four motors of the Westinghouse No. 83 type are fitted to each motor-car, one on each axle, to which they are coupled by spur-gear with a ratio of 56:20. The motors are rated at 100 h.p. and are of the enclosed four-

pole type, with laminated pole-pieces and slotted-core drum-armatures.

The collector-shoes are carried on wooden beams supported from an extension of the equalizer-bars; three of these shoes are fitted at each end of a motor-car, the two outside being positive and the center one negative. There are no power cables running through the train to connect the front and rear motor-cars together, the span of the collector-shoes being sufficient to enable all gaps in the conductor rails to be spanned by a single motor-car.

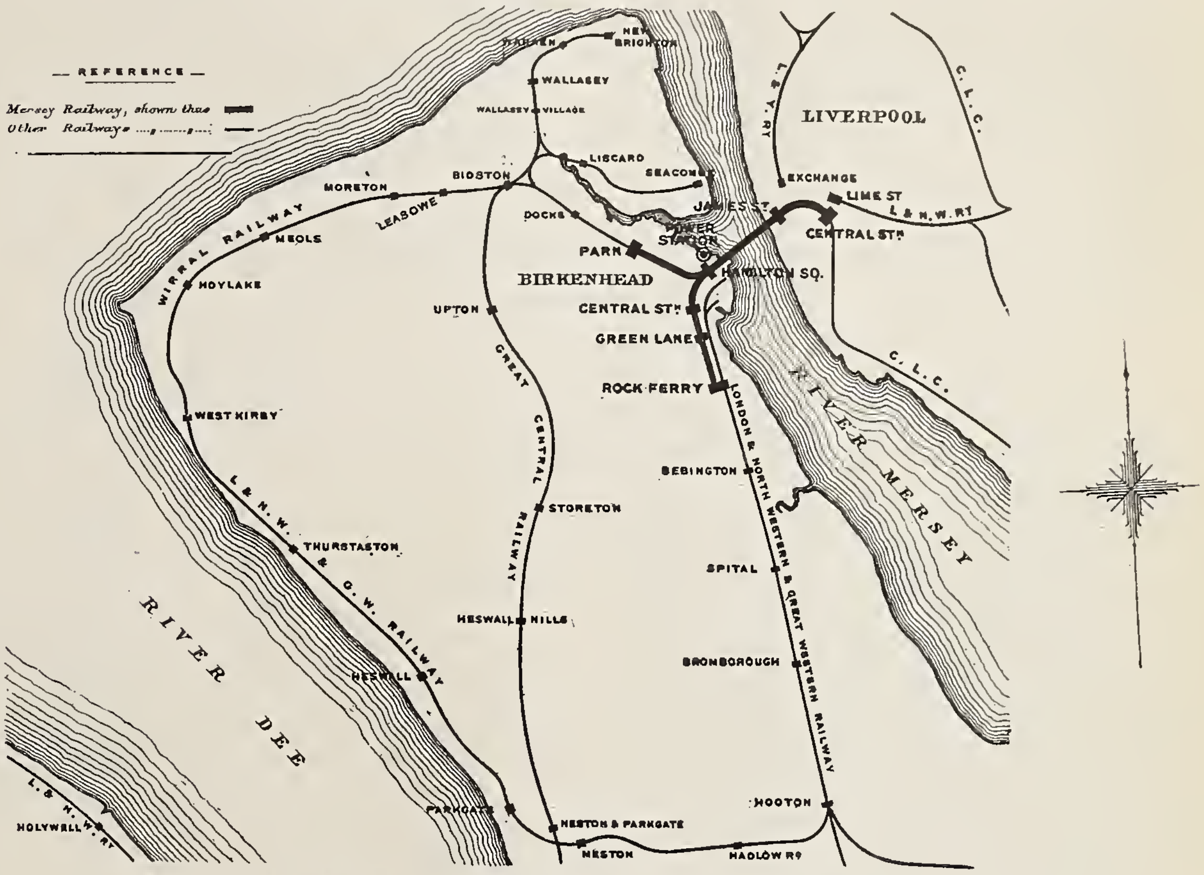
A special feature of the rolling stock is the Westinghouse system of electro-pneumatic control.

Power-House Plant.—The power-house was arranged for dealing with a train service of five-car trains (two motor-cars and three trailers) every 3 min. through the river tunnel, with alternate trains running to Rock Ferry and Birkenhead Park during the period of heavy traffic. The service originally contemplated for the period of light traffic was a 5-min. service of three-car trains through the river tunnel, but this was subsequently amended to a 3-min. service of two-car trains (one motor and one trailer). To provide for this service the plant installed consists of three units each of 1200-kw. capacity and capable of withstanding a 50-per-cent. overload for short periods; in addition, there is a storage battery having a capacity of 1000 amperes for 1 hr., and of 2000 amperes for momentary peaks. Allowing for one unit being in reserve during heavy service, the capacity of the power station is as shown in Table VII:

TABLE VII.—CAPACITY OF THE ELECTRIC POWER STATION.

	Plant.	Normal. Capacity.	Overload Capacity.
		Kilowatts.	Kilowatts.
Heavy service	Two generators	2,400	3,600
	Storage-battery	600	1,200
	Total	3,000	4,800
Light service	One generator	1,200	1,800
	Storage-battery	600	1,200
	Total	1,800	3,000

The position of the generating station is indicated on the plan Fig. 1. It measures 135 ft. by 146 ft. and is divided by a wall into engine- and boiler-rooms. The boiler-room contains nine Stirling boilers working at 160-lb. pressure per square inch, and provided with superheaters; mechanical stokers are used and also economizers of the Clay Cross type. The fuel is delivered by rail over a siding from the Dock Railway, and is taken to the overhead storage bins by a bucket-conveyer and elevator. The fuel is fed by gravity from the bins through automatic weighers into the boilers.



MAP OF THE MERSEY RAILWAY AND ITS CONNECTIONS.

FIG. 1.

The main engines are of the Westinghouse vertical cross-compound type, directly connected to the Westinghouse double-current generators. They are low-speed sets running at 94 rev. per min. with poppet valves on the high-pressure and Corliss valves on the low-pressure cylinders. The engines are run condensing, two surface condensers being provided. The generators are wound for 650 volts direct current, and are over-compounded 10 per cent.; they can also supply three-phase current at 390 volts and 25 cycles. Two 200-kw. sets are used for lighting the stations and tunnel.

The battery consists of 320 cells of the Chloride Company's make, and is controlled by an automatic reversible booster.

The switchboard is of the usual direct-current traction type and contains 19 panels.

A 30-ton travelling crane spans the engine-room.

Permanent Way.—The work of electrification which had to be carried out in connection with the permanent way may be dealt with under two headings:

(i) Additional equipment for the supply of current to the trains; and

(ii) Alterations to the track to meet the new conditions.

Additional Equipment.—The central position of the power-station permitted a distribution system to be employed which depended entirely on the conductor rails, without the use of independent copper cables as feeders.

The track is fitted throughout with insulated positive and negative conductor rails. The rails are 60 ft. long and are of the flat-bottomed type, the majority weighing 100 lb. per yard, and the remainder 60 lb. per yard.

In order to reduce the drop of voltage in the distribution system double negative rails are laid from the feeding-point at Hamilton Square 10 James Street station on the Liverpool section and to Birkenhead Central on the Rock Ferry section.

The positive rail is provided with a guard-timber throughout its entire length, and the negative bus bar of the main switchboard is connected to earth through an ammeter, so that the negative rail is practically at earth potential, rendering it quite safe for any of the staff who may come in contact with it.

The conductor rails are supported on insulators fixed on every third sleeper (*i. e.*, about 7 ft. apart), the positive insulators being 6-in. blocks of vitrified clay or reconstructed granite, and the negative insulators being 3-in. blocks of the same material. The sleepers supporting the positive conductor-rail insulators have

to be 3 in. longer than the standard, and were renewed when the line was electrified. The positive rail is fixed principally in the 6-ft. way, except at crossovers, where it had to be moved to the outside of the track. The negative rail is fixed centrally between the track rails, with its top surface 1½ in. above them.

There is a very wide divergence of opinion as to the most suitable position for the positive conductor rail. Table VIII shows the position of the positive conduction rails on the electric railways in England and also on some of the railways in America and on the Continent.

TABLE VIII.—POSITION OF POSITIVE CONDUCTOR RAILS.

	Difference in Level between Top of Positive Rail and Top of Track Rail.	From Track Gauge-line to Centre of Positive Rail.
British Railways—	Inches.	Inches.
Mersey	4½	22
Metropolitan	3	16
Metropolitan-District	3	16
Great Western	3	16
London Underground	3	16
North Eastern	3¼	19¼
Lancashire and Yorkshire	3	19½
Liverpool Overhead	3	19¼
Central London	1½	Centre.
City and South London	1½	
City and Waterloo	Level.	Centre.
American Railways—		
Baltimore and Ohio (old location)	1¾	24
" " (new location)	3½	30
Brooklyn Elevated	6	22
South Side Elevated, Chicago	6¾	20⅛
Manhattan, New York	7½	20¾
Albany and Hudson, New York	6	27
Metropolitan West Side, Chicago	6¼	20⅛
New York, New Haven and Hartford	1½	Centre.
Continental Railways—		
Paris–Orleans, France	7⅞	25⅝
Callaratae, Italy	7½	26⅝

Under steam working it was possible, in case of emergency, to work single-line between any two stations, and this facility was provided in the electric system, the arrangements made also permitting of either track having the current switched off between any two stations.

At Hamilton Square station the conductor rails of each of the three sections of track are kept separate and are connected to feeders coming from the power-station. The bonding of the conductor rails is by means of flexible bonds of the protected type. Two web-bonds underneath the fish-plates and a pair of foot-bonds are fixed to each joint. Expansion joints with special bonds are arranged at every joint in the tunnel and every fourth joint in the open.

Several alterations have been made to the track for electrical working. Under steam conditions two cross-overs were provided at each station to permit of a locomotive changing ends on a train in case of emergency. There being no necessity for this with electric trains, one crossover was abolished and the other was moved to a new position to suit the conductor-rail arrangements for single-line working. Further, in order to permit of the collector-shoes of a single motor-car spanning the conductor rails at the crossovers, the latter had to be shortened; at terminal stations, however, a special arrangement of conductor rails was adopted, rendering it necessary for the old crossovers to be lengthened. In order to fix the longer sleepers, the whole of the rails on the line had to be lifted and replaced, and every crossover was either moved to a new position, shortened, lengthened or removed altogether. The alterations to the crossovers necessitated alterations to the signals and to the locking-frames in the signal-cabins. There were also many obstructions, such as point-locks, stretcher bars, etc., which had to be cleared to make room for the conductor rails.

Hydraulic Lifts.—James Street and Hamilton Square stations are each provided with three direct-acting hydraulic lifts. These lifts are 20 ft. by 17 ft. in size and have a travel of 76.6 ft. at James Street and 87.7 ft. at Hamilton Square; they are designed to accommodate 100 passengers per lift. The low-pressure system of working is adopted, the pressure being obtained from tanks fixed at the top of a tower 119 ft. high, which forms part of the station buildings. The discharged water from the lifts runs into an underground tank fixed at a convenient level, whence it is pumped to the tower. During steam working the pumps employed were duplex steam pumps, but for these electrically-driven three-throw pumps have now been substituted.

The speed of the lifts at both stations has also been increased to enable the round trip to be performed in 3 min. with allowance for loading and unloading. It is therefore feasible to run a 1-min. lift service at each of these stations.

The pump motors at both stations are supplied with current through a special feeder direct from the power-station, and a change-over switch is arranged so that current can be taken from the conductor rails in the event of failure of the feeder.

The methods adopted for the acceleration of these lifts may be of interest. At James Street station it was decided to use pressure tanks on top of the tower instead of the gravity tanks. Accordingly, three cylindrical tanks were placed here in a triangular position (in elevation), the top tank being about half filled with air at a pressure of 25 lb. per sq. in., which pressure was maintained by a small air pump working off the connecting rod of the main pump. The old type of side-valve for controlling the admission and discharge of water to the lift cylinders was replaced by a new type of piston-valve.

At a later date the railway company accelerated the lifts at Hamilton Square, the method adopted by the author being to connect the three separate supply pipes (which supplied the three lifts) into a common header at the bottom of the lift shafts, and to replace the old controlling slide-valves with piston-valves having a much larger area.

Ventilation.—During steam working one of the most difficult matters to deal with was the efficient ventilation of the tunnel. The ventilating plant consisted of:

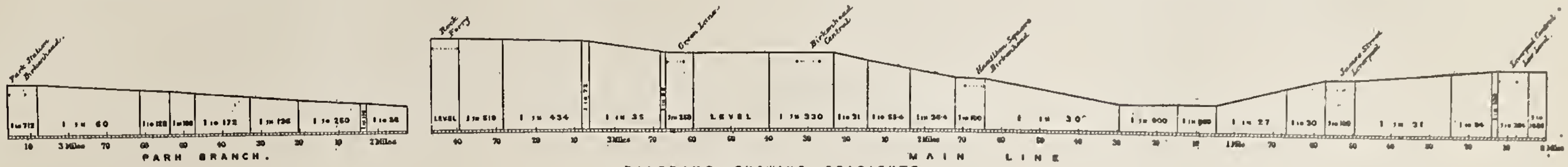
One high-speed fan (12 feet by 5 feet wide)	At Liverpool Central.
" direct-driven fan (40 feet by 15 feet wide)	Near James Street.
" " " (30 " 10 " ")	" " "
" " " (40 " 15 " ")	" Hamilton Square.
" " " (30 " 10 " ")	Between Hamilton Square and Birkenhead Central

The combined exhausting capacity of this plant was 700,000 cu. ft. of air per min. The whole of this plant has now been discarded and small electrically-driven fans have been substituted, as follows:

One fan (5 feet in diameter)	At Liverpool Central.
" " (12 " " ")	" James Street.
" " (12 " " ")	At the power station, near Hamilton Square.

The 12-ft. fans exhaust 50,000 to 60,000 cu. ft. of air per min., and the 5-ft. fan about 20,000 cu. ft. The two 12-ft. fans are driven by 30-h.p. motors, the small fan by a 5-h.p. motor.

Pumping Plant, Lighting, Workshops and Repair-Sheds.—No alteration has been made to the pumping plant in connection with the conversion of the railway, except that the old Lancashire boilers on the Birkenhead side have been done away with; the plant is supplied with steam from the Stirling boilers at the power-station.



DIAGRAMS SHOWING GRADIENTS.

FIG. 2.

The whole of the stations and tunnel are now lighted by electricity. Arc lamps are used in the booking-halls and on the station platforms, while in the tunnels 16-c-p. lamps are placed every 100 ft. on either side. The tunnel lights are controlled by switches, which are placed in the signal-cabins and so arranged that the lamps between any two stations may be switched on by the signalman at either end of the section.

Three special lighting-feeders are run from the power-station to each of the three sections of the railway. The lighting-switchboards in the station are provided with change-over switches, so that current may be taken from the conductor-rails should it become necessary.

Gas has been retained for all signal-lighting.

The workshops and car-sheds are situated at Birkenhead Central Station. In these a semi-portable boiler and engine used for driving the shop-tools was replaced by a 30-h.p. motor; and the 30-ton sheer-legs used for lifting the locomotives was replaced by a 10-ton electric travelling crane.

COMPARISON OF THE WORKING-RESULTS.

In order to compare the working-results of the two systems of traction, the author has analysed in detail the last three years of steam working which were not affected by the works being carried out in connection with the conversion of the railway (i.e. the years 1899, 1900, and 1901) and three years of electrical working (i.e. from the 1st July, 1904, to the 30th June, 1907). From this information an average year of steam and electrical working has been prepared which will be used for the purpose of comparison; and in the following Tables the expression, "total cost per annum" refers to this average year.

The working-expenses of a railway are classified under the following headings:—

Maintenance of Way and Works.
Locomotive-Power.
Repairs of Carriages.
Traffic-Expenses.
General Charges.
Rates and Taxes.
And, in the case of the Mersey Railway,
Pumping.
Ventilation.

All these items have been affected to some extent by the substitution of electricity for steam.

The proper method of making a comparison of the cost of working two dissimilar services of this description is open to argument. There are four methods and in order to obtain the fullest information the results are tabulated under each.

These methods are:

(1) *Total Cost per Annum.*—This comparison is frequently made, but it is misleading unless consideration is given to the differences in the train-service and the conditions.

(2) *Cost per Train-mile.* — The train-mile basis of comparison is not strictly applicable to the conditions which prevail on this railway at present and those which prevailed under steam working, as a reduction has been made in the weight of the trains.

(3) *Cost per Ton-mile.*—From an engineering point of view, the ton-mile basis is probably the most applicable to enable a proper comparison to be made of the effect of the electrification on the working-results of the railway.

(4) *Cost per Seat-mile.*—The seat-mile basis is one which can be used with advantage, as the carrying capacity of the railway, and therefore its capacity for earning revenue, is dependent on the seat-miles run.

The train-, ton-, and seat-mileage run during the average years under review is given in Table IX.

Cost of Locomotive-Power.—For the purpose of comparing the cost of locomotive-power of the two systems, it will be assumed that the equivalent of the steam-locomotives is:—

Electrical equipment of the trains.
Compressor-plant.
Power-station plant.
Feeder and conductor-rail equipment of the permanent way.

The trucks and bodies of the motor-cars and trailers are taken as being equivalent to the steam-coaches displaced.

Under electric working the power-station supplies steam to the pumping-plant and the electrical plant, and the expenses of the boiler-room are divided *pro rata* on the coal consumed by the respective boilers. Also the power-station supplies current for station-lighting and for the operation of

TABLE X.—COSTS OF LOCOMOTIVE POWERS.

	Total Cost per Annum.		Cost per Train-mile.		Cost per Ton-mile.		Cost per Seat-mile.	
	Steam.	Elect.	Steam.	Elect.	Steam.	Elect.	Steam.	Elect.
	£	£	d.	d.	d.	d.	d.	d.
Salaries and office-expenses	90	764	0.07	0.22	0.0005	0.0027	0.0002	0.0014
Wages connected with the working of locomotive and generating engines	4,695	6,116	3.62	1.77	0.0257	0.0218	0.0117	0.0115
Coal	7,129	5,718	5.52	1.65	0.0391	0.0204	0.0178	0.0107
Water	833	234	0.64	0.06	0.0045	0.0008	0.0020	0.0004
Oil and other stores	522	1,027	0.40	0.30	0.0028	0.0036	0.0013	0.0019
Total running expenses	13,179	13,095	10.18	3.78	0.0721	0.0466	0.0328	0.0245
Repairs and Renewals:								
Wages	2,458	2,013	1.90	0.59	0.0134	0.0072	0.0061	0.0038
Materials	1,279	2,356	0.99	0.68	0.0070	0.0085	0.0032	0.0044
Storage battery	..	379	..	0.11	..	0.0013	..	0.0007
Feeder and conductor-rails	..	638	..	0.18	..	0.0022	..	0.0012
Total cost of repairs and renewals	3,737	5,386	2.89	1.56	0.0204	0.0192	0.0093	0.0101
Total cost of salaries, running and repairs	17,006	19,245	13.14	5.56	0.0930	0.0685	0.0423	0.0360
Increase or decrease as compared with steam . . . . Per cent.	Increase 13		Decrease 58		Decrease 26		Decrease 15	

TABLE IX.—MILEAGE.

	Steam	Electric
Train-miles per year	310,944	828,674
Ton-miles per year	43,843,000	67,330,000
Seat-miles per year	96,392,000	127,548,000
Average weight of train (loaded) . . . . Tons	141	81.4
Average number of seats per train	310	154
Average weight per seat . . . . Cwt.	9.1	10.5

lifts and fans. For the purpose of this comparison the power-station costs have been reduced to represent the cost of supplying current for driving the trains, and of working the compressors supplying air for the brakes.

On this basis Table X represents the cost under the two systems for the average year under consideration.

For convenience, the items have been taken in the same order as given in the published half-yearly accounts, and the following notes explain them further:—

Salaries and office-expenses show a large increase, which is partly due to a different method of apportionment being adopted for dividing the total salaries and office-expenses among the different departments, and also to the fact that certain items charged under wages during steam working have been charged under salaries during electrical working.

The wages connected with the working of locomotive and generating engines, respectively, are drawn by the following staffs:—

Steam.	Electric.
Locomotive Drivers.	Motor-men (one per train).
" Firemen.	Cleaners.
" Cleaners.	Staff engaged on the examination of electrical equipment of the trains.
	The running-staff of the power-station.

The total coal-bill shows a decrease of £1,411 per annum, even with the considerably increased train-service under electric traction. With steam working the fuel used during the period under review was as given in Table XI, the total being 8,874 tons, costing £7,129, or an average price of 16*s*. per ton.

TABLE XI.—COAL UNDER STEAM WORKING.

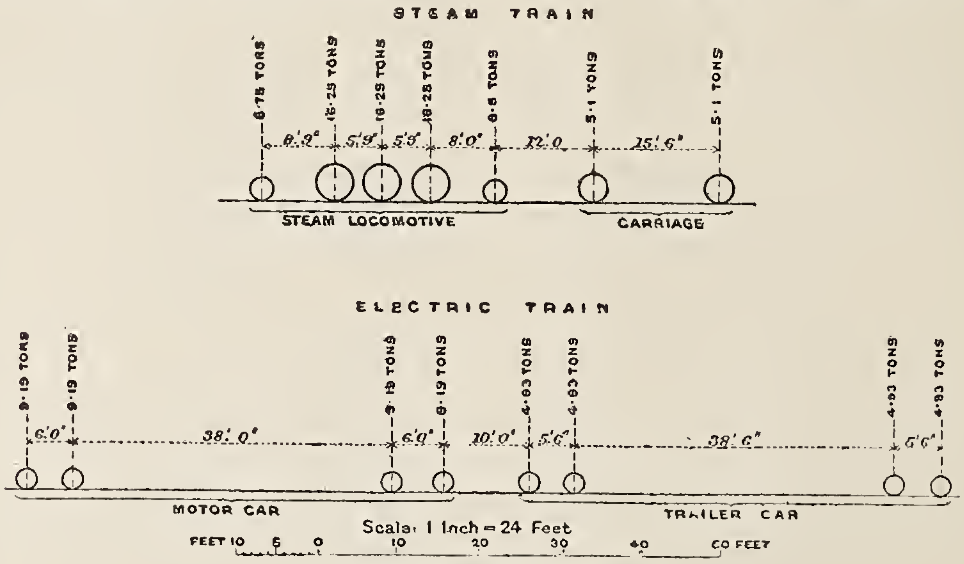
	Staffordshire Coal.		South Wales Coal.	
	Tons.	£	Tons.	£
1899	5,068	2,962	3,985	3,580
1900	4,893	4,281	3,876	3,454
1901	8,728	7,013	76	96
Total	18,689	14,256	7,937	7,130
Average per year	6,229	4,752	2,645	2,377

Staffordshire coal,	6,229 tons at	£4,752	15*s*. 3*d*. per ton.
South Wales "	2,645 " "	£2,377	17*s*. 11*d*. " "
Total per year	8,874 " "	£7,129	16*s*. 0*d*. " "

With electrical working the total quantity of fuel used at the power-station during the three years under review has been 47,400 tons of washed Lancashire slack, costing £20,652, or an average per annum of 15,802 tons, costing £6,884. Of this quantity 2,688 tons has been used for generating current for lighting, lifts, fans, etc., leaving a net amount used for train-working, to be compared with the steam working, of 13,114 tons at £5,718, equal to 8*s*. 9*d*. per ton. From these figures the following comparison is obtained:

	Steam.	Electric.
Total coal per annum........Tons	8,874	13,114
Cost per ton....................	16*s*.	8*s*. 9*d*.
Consumption per train-mile...Lbs.	64.0	35.5
" " ton-mile........	0.453	0.436
" " seat-mile........	0.206	0.230

Put in another form, the comparison indicates that with electric traction 1 lb. of coal costing 8*s*. 9*d*. per ton, will move 1 ton of load 2.29 miles at an average speed of 22¼ miles per hour; whereas with steam traction, the same weight of coal costing 16*s*. per ton would move the same load



WEIGHT-DISTRIBUTION OF TRAINS.

Fig. 4.

2.21 miles at an average speed of 17¾ miles per hour.

The consumption of water under steam working was exceptionally high, owing to the locomotives having apparatus to condense the exhaust-steam, to prevent it from being ejected in the tunnel. In order to keep the condensing water from reaching too high a temperature it was necessary to discharge the tanks and to refill with cold water after every round trip. The air-compressors which supply air for the Westinghouse brakes and controllers are situated at the terminal stations, and the water under electrical working includes the water used for cooling these in addition to that used at the power-station.

The total running-expenses show a decrease of £84 in total costs, of 6.4*d*. in costs per train-mile, of 0.025*d*. in costs per ton-mile, and of 0.008*d*. in costs per seat-mile.

The wages for repairs and renewals show a decrease in the total cost, but the cost of material is increased, and there are also the two items of (*a*) storage-battery and (*b*) feeders and conductor-rail equipment of the permanent way, which had no equivalent during steam working. The total of repairs and renewals gives an increase in total cost of £1,649, a decrease in costs per train-mile of 1.33*d*., a decrease in costs per ton-mile of 0.001*d*. and an increase in costs per seat-mile of 0.008*d*.

During steam working, the average cost of repairs of each locomotive amounted to £207 per annum, compared with £224 the average cost of repairs to each motor-car with its proportion of the power-station repairs and maintenance of the storage-battery and conductor-rail equipment. In the working of the line, the average number of motor-cars per train is 1.38, and an allowance must be made for this, which brings the corresponding figure for electric motor-cars to £309. The electric motor-car, however, as shown later, has a life of 48,064 miles, as against 17,274 for a steam locomotive.

Cost of Carriages: Repairs and Inspection, including Lighting and Cleaning.—Repairs and inspection comprise the repair and painting of the car-bodies, repair and inspection of the trucks, brake-equipment, car-platform gates, couplings and re-tiring wheels. The cost of lighting and cleaning is included under traffic-expenses, but for the purpose of this comparison the whole of the carriage-expenses will be taken together, as shown in Table XII on page 325.

The total rolling-stock costs, including lighting and cleaning, show a decrease per train-, ton-, and seat-mile, but the cost of repairs and inspection alone shows an increase per ton- and seat-mile.

The reasons for this increase are:

Increased acceleration and retardation.

Higher maximum and average speed.

TABLE XII.—COST OF CARRIAGE-MAINTENANCE.

	Total Cost per Annum		Cost per Train-mile.		Cost per Ton-mile.		Cost per Seat-mile.	
	Steam.	Elect.	Steam.	Elect.	Steam.	Elect.	Steam.	Elect.
	£	£	d.	d.	d.	d.	d.	d.
Salaries and office expenses	86	141	0.06	0.04	0.0004	0.0005	0.0002	0.0002
Wages	1,124	2,084	0.86	0.60	0.0061	0.0074	0.0028	0.0039
Materials	1,087	1,513	0.85	0.44	0.0060	0.0054	0.0027	0.0029
Total cost of repairs and inspection	2,297	3,738	1.77	1.08	0.0125	0.0133	0.0057	0.0070
Car-lighting	1,331	778	1.03	0.22	0.0073	0.0027	0.0033	0.0014
Car-cleaning	873	1,278	0.67	0.37	0.0047	0.0045	0.0021	0.0024
Total cost	4,501	5,794	3.47	1.67	0.0245	0.0205	0.0111	0.0108
Increase or Decrease Per cent	Increase 28.5		Decrease 52		Decreasc 16		Decrease 2.7	
Increase or decrease on cost of repairs and inspection only ...... Per cent	Increase 63		Decrease 39		Increase 6.4		Increase 23	

Greater number of stops per mile (no expresses).

Smaller wheels (30 and 33 inches in diameter against 43 inches) entailing,

(a) More wear on the bearings and more oil.

(b) More frequent re-turning of tires and renewals.

Automatic couplers are more expensive to maintain than ordinary couplings.

Westinghouse brake-equipment is more expensive to maintain than vacuum brakes.

All doors and gates are opened and closed at each station.

Bogie-trucks have more moving parts and therefore require more renewals than fixed wheel-bases.

Cars are painted more frequently.

Short time available for examination.

Small amount of spare stock.

Under electric traction the cost of re-tiring motor-car wheels is charged to car-repairs. Under steam traction, the driving-wheels being on the locomotives, the tire-renewals were charged to locomotive power.

The average mileage obtained from each coach per annum has an appreciable effect on the cost of maintenance and also on its life. The actual figures are:

Steam locomotive	17,274 miles per annum.
" coaches	22,672 " " "
Electric motor-car	48,064 " " "
" trailer-car	36,453 " " "

Combined Locomotive and Rolling-Stock Costs.—A factor which must be taken into account in making the comparison of the locomotive and rolling-stock costs is that it is not feasible to compare the exact equivalent of the two systems, as under electric working the "locomotive" is also a passenger-carriage, and certain portions, such as wheels, axles, brakes, etc., which for convenience are classified under car-repairs could be classified under locomotive power.

In order to eliminate such points as these, a comparison is made in Table XIII of the total cost of running and maintaining the trains, which will include the charges coming under the heading of locomotive-power and those under the heading of car-repairs, etc.

TABLE XIII.—COMBINED LOCOMOTIVE AND ROLLING-STOCK COSTS.

	Steam.	Electric.
Total costs per annum	£21,507	£25,039
Cost per train-mile	16.6*d.*	7.25*d.*
" " ton-mile	0.1177*d.*	0.0892*d.*
" " seat-mile	0.0535*d.*	0.0470*d*

Maintenance of Way and Works.—The comparison of the cost and maintenance of way and works on the same basis as the locomotive and rolling-stock costs is shown in Table XIV.

TABLE XIV.—COST OF MAINTENANCE OF WAY AND WORKS.

	Total cost per Annum.		Cost per Train-mile.		Cost per Ton-mile.		Cost per Seat-mile.	
	Steam.	Elect.	Steam.	Elect.	Steam.	Elect.	Steam.	Elect.
	£	£	d.	d.	d.	d.	d.	d.
Salaries and office expenses	158	241	0.12	0.07	0.0008	0.0008	0.0004	00.004
Permanent-way wages	2,076	1,525	1.60	0.44	0.0113	0.0054	0.0051	0.0028
Permanent-way materials	1,736	994	1.34	0.29	0.0095	0.0035	0.0043	0.0019
Total for permanent way	3,812	2,519	2.94	0.73	0.0208	0.0089	0.0094	0.0047
Repairs to—								
Signals	469	833	0.36	0.24	0.0025	0.0029	0.0012	0.0015
Stations and buildings	1,151	2,240	0.89	0.64	0.0063	0.0081	0.0028	0.0042
Total for way and works	5,590	5,833	4.31	1.68	0.0304	0.0207	0.0138	0.0108
Increase or decrease .... Per cent.	Increase 4.35		Decrease 61		Decrease 32		Decrease 22	
Increase or decrease on permanent way only .... Per cent.	Decrease 34		Decrease 75		Decrease 57		Decrease 50	

The average of three years' working with steam and with electricity thus shows a substantial reduction in the cost of maintenance of the permanent way. As it may be said that this period is not long enough to permit of a reliable comparison being made, the cost five years' working under steam and five years' under electricity (the longest period obtainable) have been analyzed. The average per year for the permanent way only for this longer period gives the following results:

	Steam. 1897 to 1901.	Electric. July, 1903, to June, 1908.
	£	£
Wages	1,900	1,537
Materials	1,756	932
Total	3,656	2,469

When electric working was introduced, the Mersey Company had to take over the maintenance of ½ mile of track which had previously been maintained by the London and North Western and Great Western Joint Railways, so that in the comparison there are not only the extra trains to be considered but also the extra length of track. If the comparison is made per mile of track the following is the result:

	Steam.	Electric.
	£	£
Wages	455	328
Materials	420	198
Total	875	526

With regard to the wear of the rails, the experience on this railway shows that if a proper comparison is made, the rails are more durable under electric traction than with steam. The actual life in years and the actual work the rail will stand are both greater.

During five years of steam working the average weight of new rails used per annum was 175 tons, and during the five years of electric working the average weight per annum was 192 tons.

Table XV shows the comparative life of rails under the two systems.

This comparison in Table XV is with rails of the same quality in both instances, but recently rails of a tougher quality have been introduced, and a much longer life is anticipated from these.

The repairs to signals show an increase in total cost, which is due to the largely increased train-service and to the necessity for having a larger staff to attend to the inspection and repairs.

The increase in cost of the repairs to stations and buildings is £1,091, due partly to the much larger number of people who use the stations, steps, etc., and partly to the large amount of improvement work which has been carried out to render the stations more attractive.

Hydraulic Lifts.—The large increase in the number of trains has called for a considerable increase in the number of lift-trips. In making a comparison of the lift-service, the best unit to use is the lift-mile unit,

TABLE XV.—WEAR OF RAILS.

		Steam.	Electric.
Length of double track maintained	Chains	334	375
Weight of new rails used per annum	Tons	175	192
Ton-miles run by trains per ton of rails used		236,000	350,000
Total weight of rail in track	Tons	1,130	1,270
Annual consumption as a percentage of total rails in track	Per cent.	15½	15.1
Therefore average life is	Years	6.45	6.6
Average rolling load over each track before it is renewed	Tons	32,000,000	47,500,000

and Table XVI shows the total cost and also the cost per lift-mile.

No actual record is kept of the number of trips made by the lifts, but the number of trips and mileage shown may be regarded as approximately correct.

TABLE XVI.

	Total Costs per Annum		Cost per Lift-mile.	
	Steam.	Electric.	Steam.	Electric.
	£	£	d.	d.
Wages, including running and repairs, but exclusive of cage-attendants	599	672	33.5	11.6
Oil, waste, and all other stores	363	489	20.3	8.5
Power-costs	562	575	31.4	10.0
Total	1,524	1,736	85.2	30.1

	Steam.	Electric.
Approximate lift-trips per annum	276,276	888,164
Approximate lift-miles per annum	4,293	13,832

Pumping.—Under steam working this work was divided evenly between the two sides of the river. Under electric working about 75 per cent. is done at Birkenhead and 25 per cent. at Liverpool, the steam at the former place being supplied from the power-station boilers. The effect of this has been to reduce the cost of pumping from £6,739 per annum under steam working to £5,780 per annum under electric working, showing a decrease of £959 per annum.

Ventilation.—A considerable economy has been effected in the cost of ventilation, the cost having been reduced from £5,430 per annum under steam working to £332 per annum under electric working, a decrease of £5,098 per annum.

Electric Lighting, Gas, Water, and General Stores.—The cost of the lighting to the stations and tunnels, of the supply of water, and of general stores was £2,314 per annum under steam working and is now £3,596 per annum under electric working, showing an increase of £1,282 per annum. This is accounted for by the lighting of the tunnel, and the considerably increased lighting of the stations, workshops, etc.

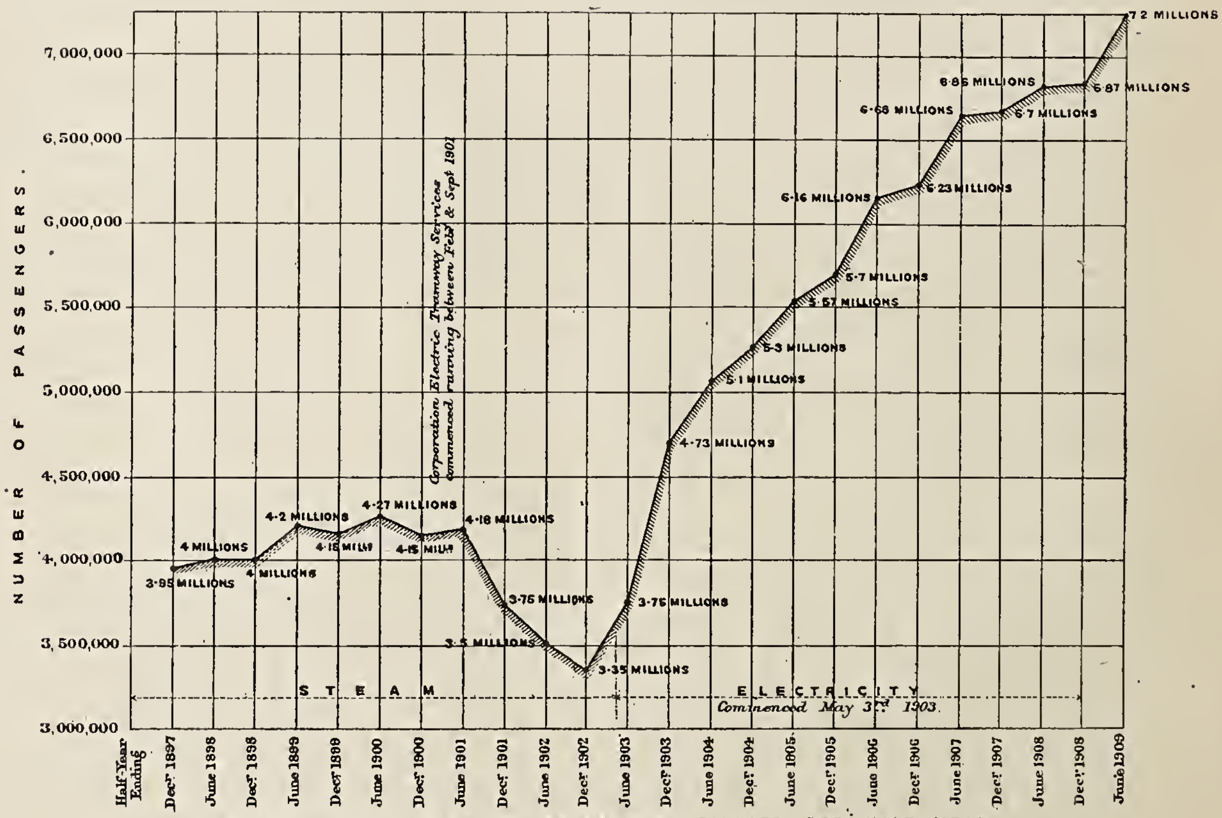
Telegraph- and Telephone-Expenses.—These under steam working were £249 per annum and are now under electric working £363 per annum, showing an increase of £114 per annum.

Total Cost of Operating and Maintaining the whole of the Works, Plant, etc., comprised in the Engineering and Locomotive Departments.—The foregoing items represent the total cost of operating and maintaining the whole of the works, plant, etc., comprised in the engineering and locomotive departments and are summarized in the following Table:

TABLE XVII.

	Steam.	Electric.
Total cost per annum	£43,353	£42,679
Cost per train-mile	33.55*d.*	12.30*d.*
" " ton-mile	0.238*d.*	0.152*d.*
" " seat-mile	0.108*d.*	0.081*d.*

In dealing with the effect of the electrification on the working-results, the foregoing figures show the effect from an engineering point of view; but in order to obtain a proper comparison it is necessary to go further and deal with the total expenses of the railway.



CURVE SHOWING NUMBER OF PASSENGERS CARRIED PER HALF-YEAR.

FIG. 3.

In addition to the engineering expenses shown in Table XVII, there are the traffic-expenses and general charges, etc., and the total expenses including these items are as given in Table XVIII.

TABLE XVIII.—TOTAL EXPENSES OF THE RAILWAY.

	Steam.	Electric.
Total expenses per annum	£62,897	£67,442
Cost per train-mile	48.5*d.*	19.5*d.*
" " ton-mile	0.344*d.*	0.240*d.*
" " seat-mile	0.156*d.*	0.127*d.*

In making a comparison of the total expenses it is necessary to take into account the interest on the additional capital required for the conversion of the system of traction. This interest is equal to £14,800 per annum or 4.3*d.* per train-mile and 0.0528*d.* per ton-mile; and the following Table XIX gives total expenses, including the interest.

TABLE XIX.—TOTAL EXPENSES OF THE RAILWAY AFTER ADDING INTEREST ON ADDITIONAL CAPITAL TO THE EXPENSES OF THE ELECTRICAL SYSTEM.

	Steam.	Electric.
Total cost per annum	£62,897	£82,242
Cost per train-mile	48.5*d.*	23.8*d.*
" " ton-mile	0.344*d.*	0.2928*d.*
" " seat-mile	0.156*d.*	0.1548*d.*

SUMMARY OF THE EFFECT OF ELECTRIFICATION OF THE MERSEY RAILWAY.

Briefly summarized, the result of electrification of the railway has been to give the results shown in Table XX.

When considering the effect of the new service as regards the earning-capacity of the railway, it would not be a fair comparison to take the revenue during the period reviewed for the working expenses, because during the steam working the receipts were falling and during the electrical working they have shown a steady increase each half-year, corresponding with the increase in the number of passengers. The variation in the number of passengers carried per half-year from July, 1897, to June, 1909, is shown in Fig. 3.

TABLE XX.

		Steam.	Electricity.
Number of trains per hour, light traffic		8	20
" " " " " heavy traffic		12	20
Average speed, including stops	Miles per hour	15.6	19.9
Time required for journey including stops	Main line Mins.	15	11
	Branch line "	10	8
Train-miles per annum		310,944	828,674
Ton-miles per annum		43,843,000	67,330,000
Seat-miles per annum		96,392,000	127,548,000
Average weight of train (loaded)	Tons	141	81.4
Total expenses per train-mile, after allowing interest on additional capital for electric works		48.5*d.*	23.8*d.*
Total expenses per ton-mile, etc		0.344*d.*	0.2928*d.*
" " " seat-mile, etc		0.156*d.*	0.1548*d*

Towards the end of steam working the Corporation of Birkenhead opened a system of electric tramways which had the effect of bringing down the railway's receipts considerably; the tramways, being owned by the same Corporation who worked the ferry-service, they were specially laid out to feed that service, and the extra facilities thereby given to passengers to reach the ferries caused a large number to leave the railway.

The decreasing traffic under steam and the increasing traffic under the electric working did not materially affect the cost of working, and a comparison is therefore made in Table XXI of the revenue during (*a*) the half-year before the tramways began to affect the receipts; (*b*) the last complete half-year of steam working: and (*c*) the half-year of electrical working ending June, 1908.

In the electrical working the total seat-miles for the foregoing half-year equaled 68.80 millions and the total passenger-miles 13.7 millions. This represents an average loading of 19.96 per cent. of the total seating-capacity provided.

TABLE XXI.—PASSENGERS CARRIED AND REVENUE EARNED.

	(*a*) Steam Half-Year ending June, 1901.	(*b*) Steam Half-Year ending December, 1902	(*c*) Electric Half-Year ending June, 1908.
Train-miles	154,272	155,039	408,134
Ton-miles . . . Millions	22.6	21.8	33.727
Seat-miles . . . "	50.9	48.1	68.8
Passengers	3,728,292	2,844,708	5,719,572
Season-tickets	2,028	1,595	5,882
Total passengers, including allowance for season-tickets	4,181,192	3,357,688	6,867,834
Train-miles run per passenger	0.037	0.046	0.059
Ton-miles run per passenger	5.41	6.49	4.91
Seat-miles run per passenger	12.17	14.33	10
Passenger receipts	£35,682	£26,489	£47,868
Total receipts	£38,327	£29,470	£51,784
Passenger receipts per train-mile	55.5*d.*	41*d.*	28*d.*
" " " ton-mile	0.31*d.*	0.292*d.*	0.341*d.*
" " " seat-mile	0.168*d.*	0.132*d.*	0.167*d.*
Receipts per passenger	2.06*d.*	1.89*d.*	1.67*d.*

WORKING RESULTS OF THE ELECTRICAL SERVICE.

A few general notes on the working of the electrical service may be of interest. The railway, as will be seen from Fig. 2, has exceptionally heavy gradients, the three worst places on the line being: (*a*) At James Street Station on the up journey, where the trains are standing on a 1 in 100 up grade in the station, with a 1 in 31 up grade commencing near the end of the platform, so that before the train can be fully accelerated it is on the heavy grade where it has to be brought up to full speed. (*b*) At Hamilton Square on the down side, the same condition applies. (*c*) At Green Lane on the down side the 1 in 35 grade commences at the end of the platform, though the station itself is on the level.

These heavy gradients do not cause any difficulties in operation, but they have a marked effect on the energy required for operating the trains. Table XXII shows the current consumption, volts, and speed of a five-car train on a return journey on the main line during heavy traffic. The current consumption shown does not include the operation of the motor compressors for the Westinghouse brakes.

Owing to the limited time available for inspection a large staff has to be available for dealing with the trains as they are brought out of service for inspection purposes. The trains are examined by the inspection staff, who also attend to minor repairs every 2 days or after running about 300 to 400 miles. The general practice is for controllers, lights, car-doors, bells, motors, brake-blocks, brake-levers, motor-suspenders, springs, wheels and lubrication of bearings to be examined every alternate day. The controller-magnets are examined weekly; the multiple-control wiring and connections are examined and tested monthly; the triple valves are seen to every 3 months, and the brake-cylinders every 6 to 9 months.

After running about 38,000 miles the motor-cars are taken into the shops for a thorough overhaul, which consists of completely dismantling the trucks, annealing the equalizer bars, relining the axle-bearings, and turning-up wheel-tires, etc. The motor-bearings are relined and the commutators are skimmed up every alternate overhaul. The trailer-cars run from 50,000 to 60,000 miles, after which they are brought in for complete overhaul.

The tires of both motor-cars and trailer-cars have to be turned up more frequently than would otherwise be the case, owing to the curves on the line being practically all in the same direction. The average life of motor-car tires is about 180,000 miles. As regards trailer tires, sufficient time has not elapsed to make a definite statement as to the average life, but it will be over 250,000 miles.

The brake-blocks used are chilled on the face to a depth of 5/8 inch and have an aggregate life of 10,000 miles for motor-cars, and of 13,500 miles for trailers. When electrical working was first commenced, ordinary cast-iron brake-blocks were tried and gave an average life of 2,200 to 2,500 miles.

The life of the motor-pinions averages about 4 years, representing 200,000 miles. None of the gear-wheels on the axles have yet worn out, although some of these have done 350,000 miles, and it is anticipated that a further life of 2 years will be obtained.

TABLE XXII.—DETAILS OF UP AND DOWN TRIPS ON THE MAIN LINE.

	Time of Run.	Time Current is on.	Average Current.	Average Pressure.	Average Speed.	Energy Consumed. Total	Energy Consumed. Per Ton Mile
	M. S.	M. S.	Amperes.	Volts.	Miles per hour.	Kilowatt-hours.	Watt-hours
Down Trip—Liverpool Central (Low Level) to Rock Ferry.							
Liverpool Central to James Street	1 40	0 10	586	500	19.8	0.814	10.9
James Street to Hamilton Square	2 40	1 5	808	553	26.44	8.067	50.48
Hamilton Square to Birkenhead Central	1 45	1 5	1,084	551	18.0	10.784	151.03
Birkenhead Central to Green Lane	1 30	0 30	830	565	17.5	3.907	65.66
Green Lane to Rock Ferry	2 20	1 5	1,006	536	19.28	9.735	95.44
Summary	9 55	3 55	943	541	20.8	33.307	71.24
Up Trip—Rock Ferry to Liverpool Central (Low Level).							
Rock Ferry to Green Lane	2 5	0 50	610	544	21.6	4.609	45.18
Green Lane to Birkenhead Central	1 20	0 40	810	528	19.68	4.752	79.86
Birkenhead Central to Hamilton Square	1 30	0 30	820	594	21.00	4.059	56.84
Hamilton Square to James Street	2 20	1 0	644	580	30.21	6.225	38.95
James Street to Liverpool Central	2 0	1 35	940	557	16.5	13.816	184.7
Summary	9 15	4 35	780	561	22.3	33.461	71.57
Average of up and down trips	9 35	4 15	855	551	21.5	33.384	71.41

Cooling Towers For Steam and Gas Power Plants

Natural Draft and Auxiliary Draft Types

By J. R. BIBBINS

Two important factors contribute to the effective operation of a cooling tower: (a) One factor is the well-known characteristic of a natural draft tower considered as a "chimney"—an increase in capacity with an increase in temperature head (see Fig. 9). In steamwork, especially with high vacuum, the general range of condenser discharge temperature is relatively low; in gaswork, on the other hand, it is high. Pistons are today operated at temperatures of 140 degrees to 160 degrees, cylinders from 120 degrees to 150 degrees, occasionally higher. Owing to the small volume of water in the minor circuits, such as valves, packings, etc., these temperatures have little effect upon the average outlet temperature of the engine, which ranges from 115 degrees to 130 degrees Fahr. in the large engines, and 140 degrees in the smaller sizes and verticals. This would correspond to a very poor vacuum in a steam plant, not more than 24 in. to 26 in.; practically out of the question in turbine-work. However, this high temperature results in a high rate of heat dissipation in the tower per unit of cooling surface, with a corresponding reduction in the bulk of the tower.

(b) The second factor relates to developments in the efficiency of the steam condensing plant. The function of a condenser is, primarily, that of a water heater and the measure of its efficiency as a condensing vessel is the difference between the temperature of the exhaust steam and that of the discharge water. A theoretically perfect condenser would heat the outgoing cooling water exactly to the temperature of the incoming steam. But in practice from 10 degrees to 50 degrees difference exists, depending upon the type of condenser and the volumetric ratio of water to steam. A good surface condensing plant with a dry-air pump should operate at 28 in. vacuum with a temperature difference of 15 degrees; often it is more, and the author has seen 25 degrees to 40 degrees difference in some of the largest stations in the country. A good barometric or centrifugal jet condenser, with a dry-air pump, should operate with a temperature-difference of 10 degrees to 15 degrees. Although it is possible for this type to operate on less, perhaps 5 degrees to 10 degrees, commercial practice rarely concedes such results.

A very recent development in air pumps has made it possible to operate on a still smaller difference, from two to five degrees with a reasonable water ratio, and even to approximate theoretical conditions. All this is in the right direction. The smaller this temperature differential, the higher the maximum inlet temperatures permissible for a given set of conditions—both water to condenser and air to tower. The curves in Fig. 1 show this relation in approximate form—vacuum possible with varying condenser and fixed cooling tower performance. For example, with 28 in. vacuum, 20 degrees differential in the condenser, water ratio 60, and 15 degrees cooling in the tower, the highest possible temperature of outside air would be 65 degrees Fahr. With warmer air, the vacuum would necessarily fall. Under the same conditions, with 10 degrees differential, a maximum air temperature of 76 degrees would be permissible; and with five degrees, 81 degrees inlet air. It is therefore apparent that the tendency of modern condenser development toward higher efficiencies will materially assist in the successful operation of cooling towers under extremely adverse conditions.

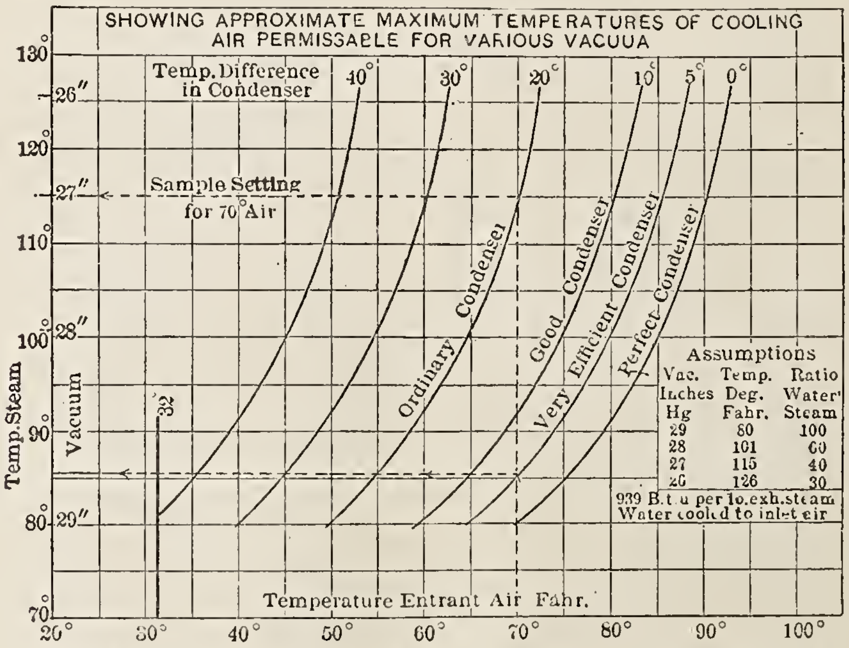


Fig. 1—MAXIMUM AIR INLET TEMPERATURES FOR VARIOUS VACUUMS

ELEMENTS OF DESIGN

The most important elements entering into the design may be considered under the following heads, having special reference to the enclosed type of cooling tower, which for a given floor space has by far the greatest cooling capacity: (a) Type of cooling surface; (b) Water distribution system; (c) Draft and air distribution.

Following are a number of essential points that seem to the writer to have a most important bearing upon any type of tower designed for maximum duty and efficiency: (a) All tortuous or unduly obstructed passages should be avoided. It is of no advantage to give ample spacing in one part of the tower and contract it in another, unless sufficient stack height is provided to overcome the additional resistance. (b) Avoid free falling water. It should be distributed so as to descend clinging to some form of wetted surface. (c) Avoid open spaces in the mat work, usually occurring at points where it is difficult to fill in between the frame of the tower. This will "short-circuit" and invariably diminish the effectiveness of the working sections. (d) Reduce the working sections to the minimum possible height, adding extra stack if necessary. The power required to elevate the water is important, and the working height of the tower is lost, even in a closed condenser circulating system. (e) Baffles or variable spacing are often necessary to obtain uniform air distribution. (f) A settling basin of liberal depth is always advisable in order that entrained air may separate. In all jet-condenser installations, this

*Abstract of a paper presented at the New York (Dec., 1909) meeting of the American Society of Mechanical Engineers.

is extremely important, owing to the amount of air returned to the condenser; and even in surface installations, this air will find its way back to the condenser via the feed water with the result of impaired vacuum. (g) All wooden mat surface is subject to swelling. Means should be taken to insure permanent alignment; otherwise serious reduction in draft area and capacity may be encountered. (h) For maximum effectiveness, a cooling surface is required which provides an uninterrupted descent of water, in a thin film at all times in intimate contact with ascending air. If any interruption is necessary, the descending sheet should be guided into place to avoid free fall.

PRESENT TYPES

The various types of cooling systems now in use naturally group themselves into a few general classes:

(a) The simple spiral-spray nozzle discharging into an open pond.

(b) The simple tray type, with water dripping through perforations, and cooling entirely by means of transverse air currents from the side. Here no direct draft is possible, and the tower has no direct cooling surface. The trays operate simply to arrest the fall of the water. In this respect, the type is a simple mechanical refinement of a rough frame tower filled with brush, such as has often been employed in temporary power work. It is, however, comparatively inexpensive, and under some conditions, may be utilized to advantage.

(c) The simple cascade type, constructed either of wood or of corrugated sheets, in which a considerable part of the cooling is by actual conduction. This cascade system seems to have been overrated. In one prominent plant, the author understands it to have been a decided failure; in any form it is extremely primitive and not in accordance with effective design.

(d) Another representation of the simple types of construction is the multiple cascade (See Fig. 2). Here the water is simply interrupted at short intervals and no cooling surface is installed. It is evident that successful operation is dependent entirely upon the accuracy with which the trajectory of the falling particles can be predetermined in the spacing of the trays and maintained in the subsequent operation of the tower. This would require an absolutely constant head. A tower at Colorado Springs utilizes the construction as in Fig. 2b, a horizontal slotted surface with wind shield to prevent spray loss. This tower gives 40 degrees cooling in fair weather. The humidity, however, is around 50 per cent. (relative).

(e) Several American towers are constructed simply of horizontal lattice-work, usually of cypress, the numerous tiers being staggered in order to break more effectively the fall of water (see Fig. 2c). In some, the upper and lower faces of the lattice-work are believed to lessen the resistance of descending water and ascending air. Cooling water is distributed by atomizing nozzles, by numerous spray pipes, or by Barker's

3e, which has been introduced into this country, advances one step in introducing vertical cooling surfaces in transverse tiers. But most important is the attempt to guide the water downward in the form of a film, by forming each slat with a sawtooth edge, meeting the lower transverse slats and guiding the water streams thereon. The designer has evidently appreciated the necessity of avoiding a free fall of water and has deliber-

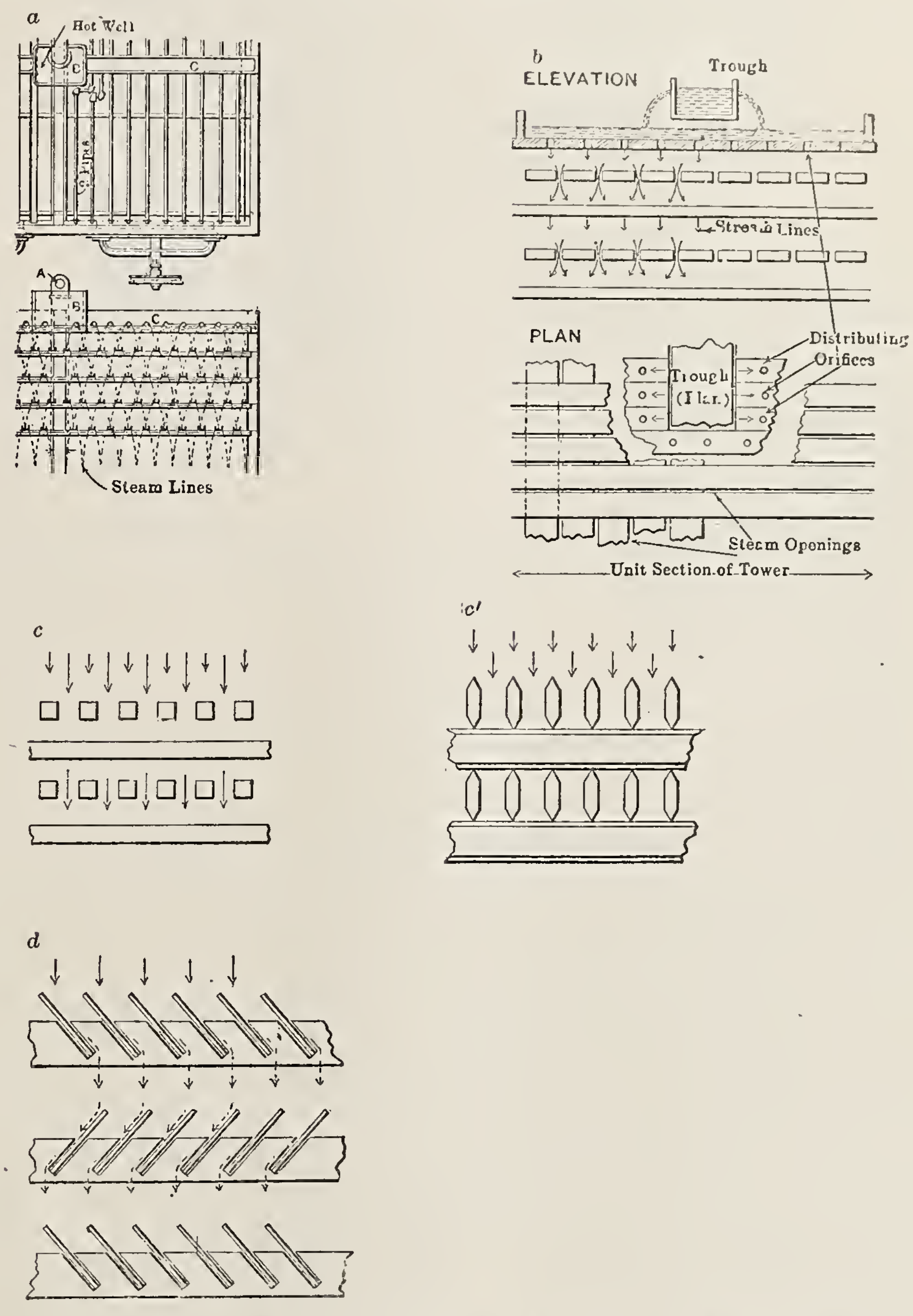


Fig. 2—TYPES OF COOLING SURFACES EMPLOYED IN VARIOUS TOWERS

Mill. This type evidently does not lend itself readily to natural draftwork, owing to the serious resistance offered to the draft by the lattice-work.

(f) A modification of the multiple cascade system, used in the German tower, Fig. 2d, endeavors to utilize partly the inclined deflecting surface as a cooling medium, although it is a question whether this is of much effect owing to the fact that the ascending air in all cases impinges on the lower surface of the deflectors, and not on the upper wetted surface.

(g) Another German design, Fig.

ately piped the water from the flume to small troughs serving the upper row of slats. An American builder has modified this system (Fig. 3f) by practically discarding the numerous tiers of slats for vertical ones extending halfway down the tower, turning them 90 degrees at the middle of the tower, ostensibly for the purpose of equalizing air distribution. However effective this may be, we have here the desirable elements of continuously wetted surface and no free fall of water.

(h) A well-known American type, resembling the multiple surface Ger-

man tower (Fig. 3e), employs numerous tiers of galvanized iron or tile cylinders, with a distributor at the top, of the Barker's Mill type, propelled simply by the reaction of the issuing jets.

(i) Several builders employ con-

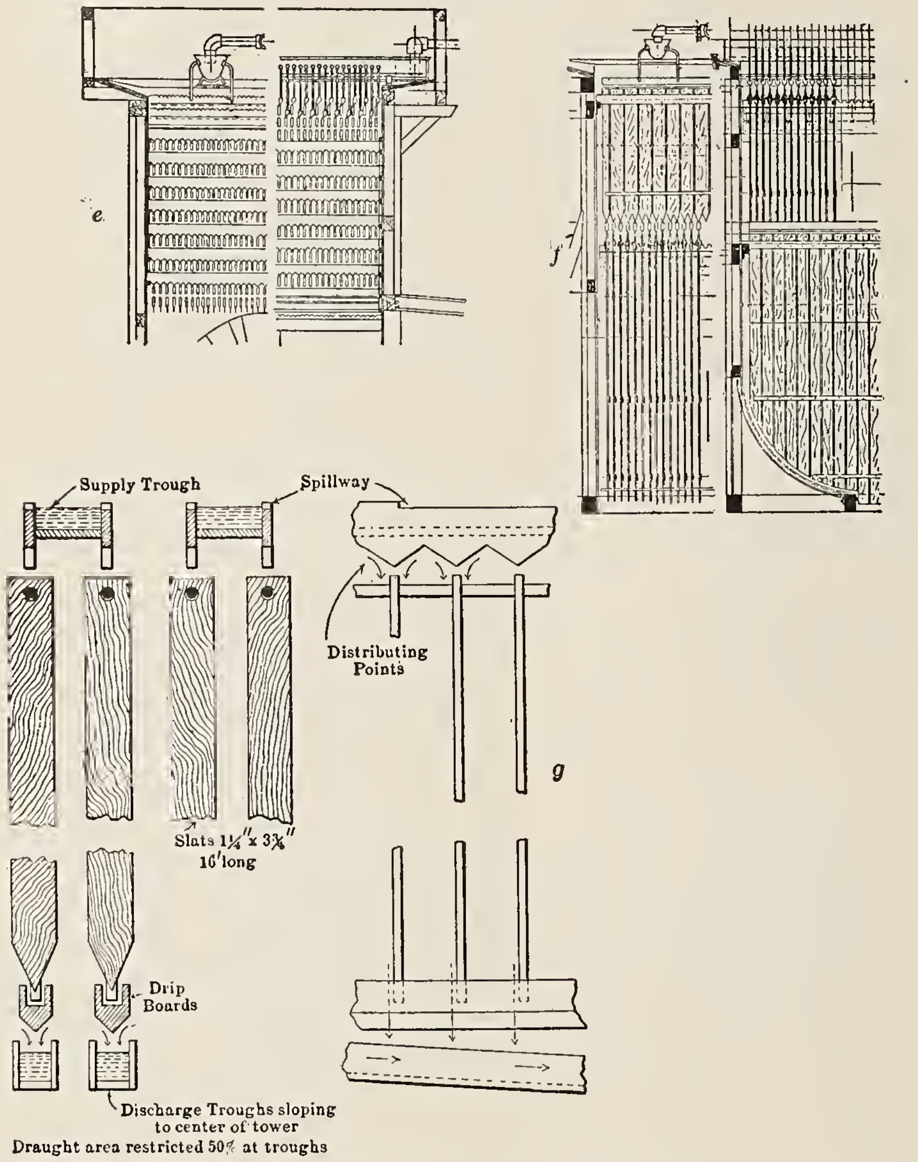


Fig. 3—TYPES OF COOLING SURFACES

tinuous galvanized iron surfaces from the top to the bottom of the tower, either in the form of corrugated sheathing or of wire mesh, the water being carefully guided to the sheets so as to avoid free fall. The principle is right. With the close spacing permissible, a most intimate contact of the air and descending film may be maintained.

(j) Coming now to exclusively wooden mat construction, an example of the attempt to combine in a single slat construction all the above-mentioned desirable features is that shown in Fig. 3g. This tower is of the natural-draft type with a side flume communicating with numerous transverse ducts which discharge upon continuous vertical slats, the sawtooth construction being employed to guide the water on the wetted surface. At the bottom, instead of allowing the water to fall freely into the receiving basin, each descending sheet is caught in a small trough and conveyed to the center of the tower, where it descends without retarding the ascending current of air. These distributing troughs reduce the effective draft area of the tower by about 40 per cent.; but, on the other hand, the reduction in area is fairly uniform throughout the tower, and the area correspondingly diminished. This type is extremely effective.

LATH MAT CONSTRUCTION

In a design originated in Detroit, Mich., shown in detail in Fig. 4, an attempt was made to subdivide the cooling surface into sections or tiers, while maintaining the advantages of continuous vertical surface. This it was thought would facilitate the construction and repair of the tower; it was also hoped to avoid the distortion of the mat surface occasioned by the swelling of the timber, which it is hard to avoid when long slats are employed. The important point in the design was the reduced cost of construction. With the exception of the sheet metal shell furnished by a local boiler maker, the tower was built by unskilled labor employed about the station, and its total cost, including shell, concrete and brickwork, material and labor, was in the neighborhood of $1,350, serving a 1000-h.p. engine-driven plant. The shell was designed self-supporting with an independent internal framework for supporting the weight of the mass. Wooden sheathing could have been used to good advantage, however, and the entire tower constructed by unskilled labor.

The mat surface was constructed of common wood lath, assembled on a form, with iron nails protected from corrosion by being embedded in the

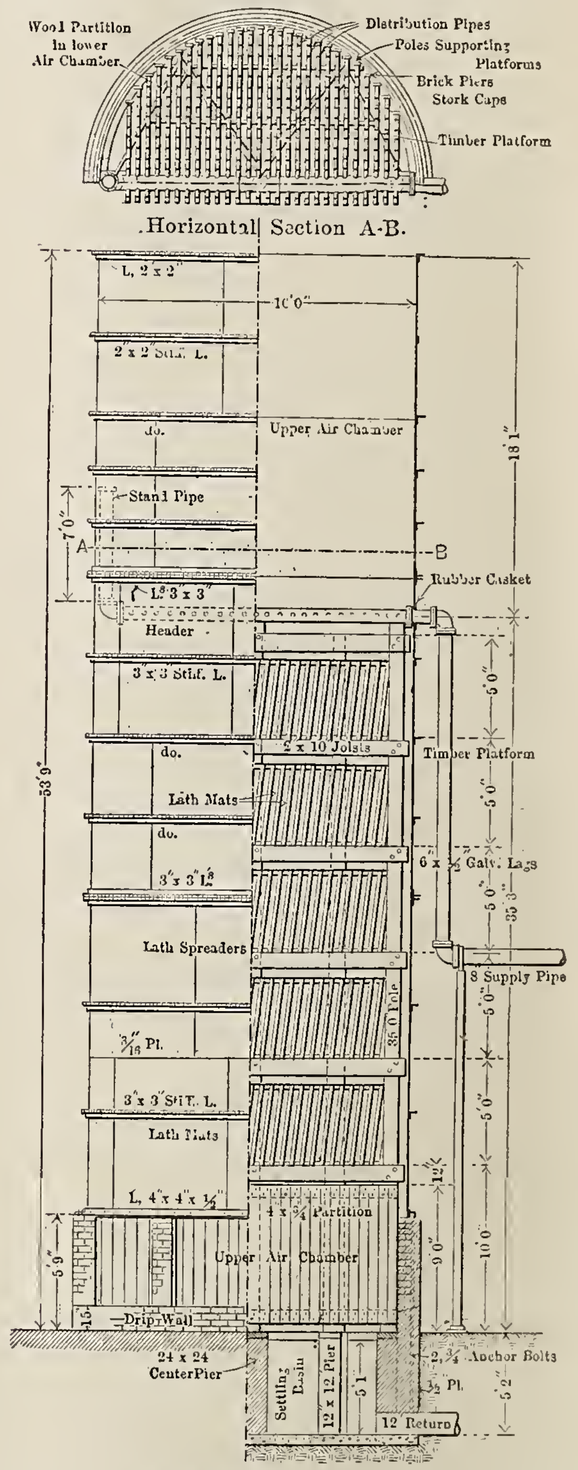


Fig. 4—EXPERIMENTAL NATURAL DRAFT TOWER AT DETROIT

wood. Mat details are shown in Fig. 5. These lath mats produced a very desirable form of cooling surface. The rough surface kept the descending stream in constant agitation, and there was a sufficient slope to prevent free falling water for any great distance, and also to constrain the ascending air to slice upward through the interstices, thereby bringing into use both sides as well as both edges of the lath. Thus a cooling surface of approximately 20 sq. ft. per running foot of lath mat was obtained. The various tiers were readily assembled in

succession, working from the shell inward until full. Uniform water distribution was effected by means of the pipe-spray system, with laterals spaced like the mats below. Two series of tests* were made at Detroit at different times, first, with only the two upper tiers, and finally with all the mats in position. Tables II and III and Figs. 8 to 10 show the relation between the various quantities observed. It was very noticeable that the rate of heat dissipation in B. T. U. per square foot per hour was considerably higher for the uncompleted tower with only about three-fifths of the mats in operation. However, by the addition of the remaining mat surfaces the tower was enabled to work on lower water temperatures, and we should therefore expect a lower rate of heat dissipation. This would indicate that the upper tiers of towers are more effective than the lower. The heat dissipation during the tests on the complete tower ranged from 200 B. T. U. to 300 B. T. U. per square foot of surface per hour under normal conditions, and this could undoubtedly have been increased in a carefully constructed tower with suitable condenser apparatus.

Although fairly successful, this experimental design might have been considerably improved. By straddling the supporting joists in the manner shown in detail in Fig. 6 the various tiers of mats may be brought together into a practically continuous surface from top to bottom, thus entirely preventing the fall of water. At the bottom, the obstruction to draft may be prevented by employing deflecting troughs under each mat to convey the water to the center of the tower, as in the Moser tower, Fig. 3g. A better distribution system in the form of horizontal slotted laterals discharged upward and overflowing directly on the respective mat sections is shown in Fig. 7.

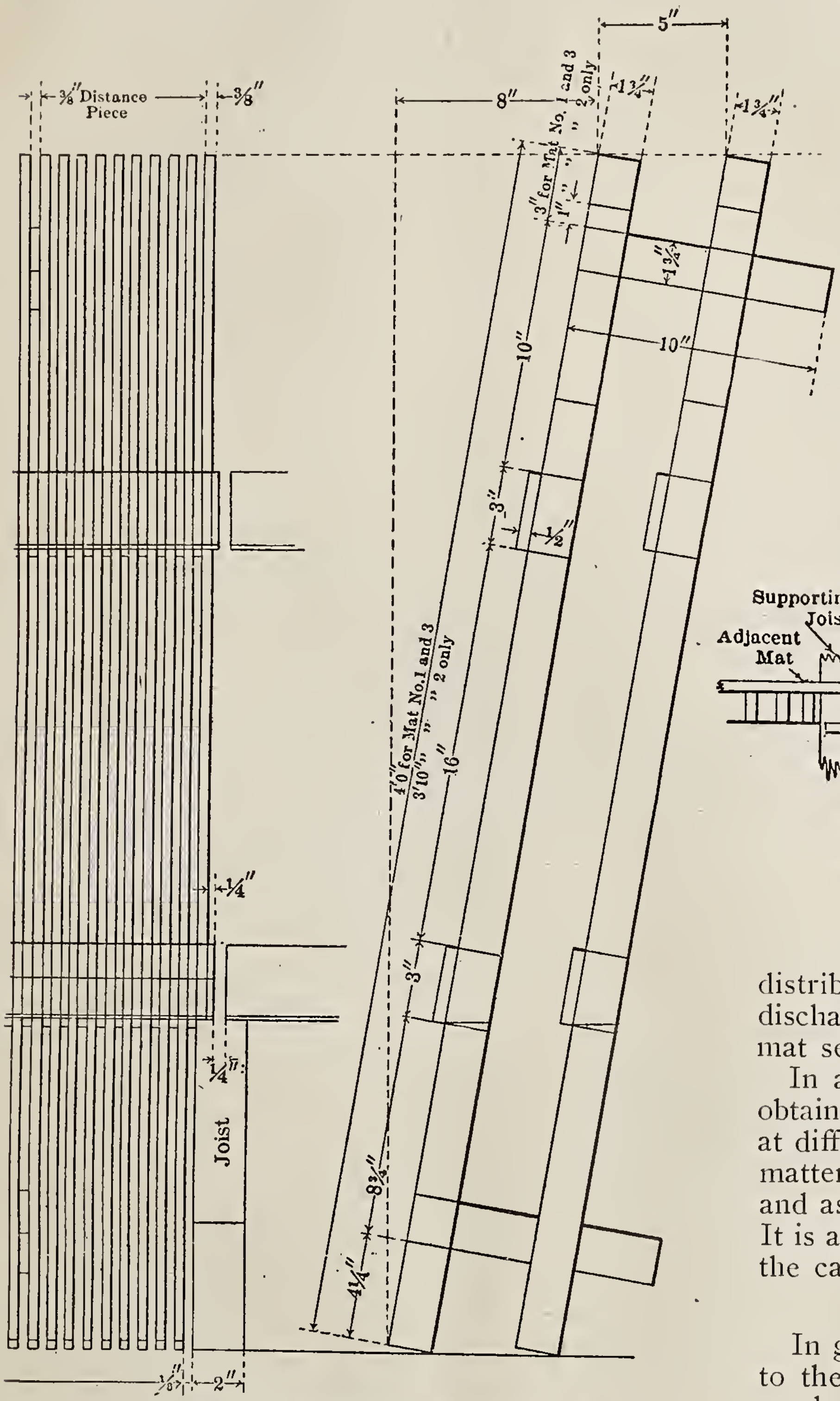


Fig. 6—DETAILS OF SECTIONAL MAT SURFACE

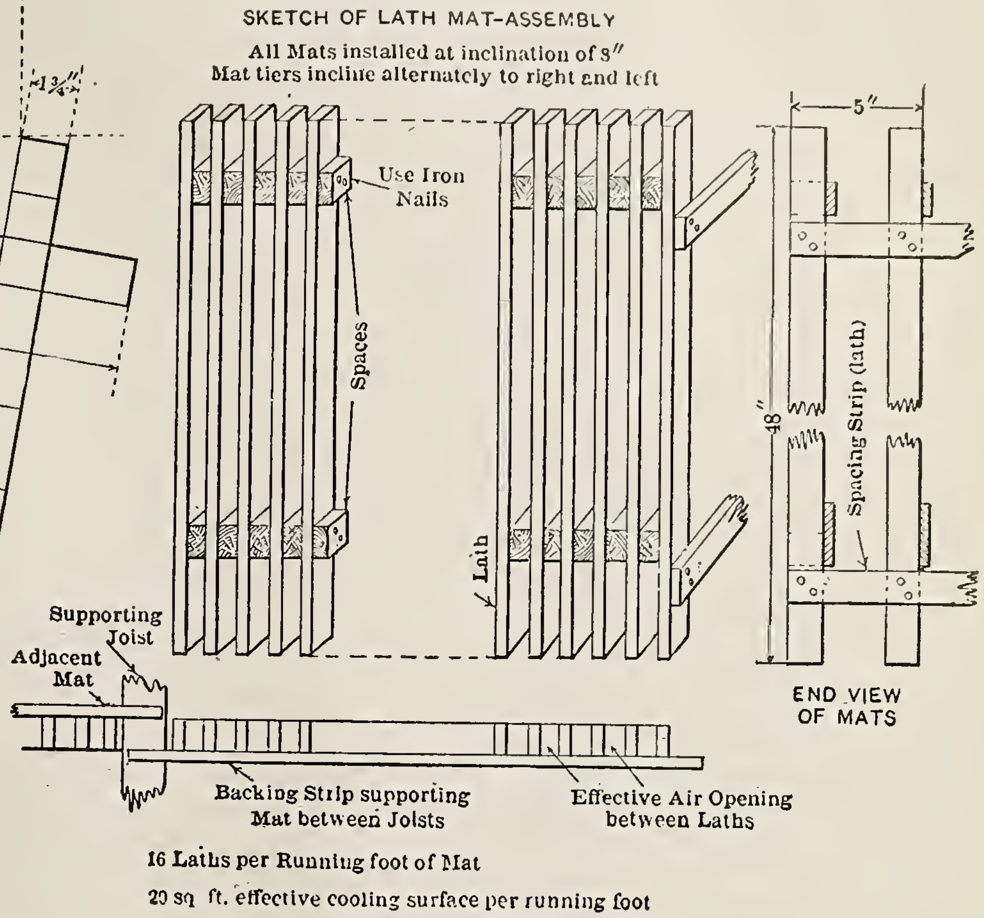


FIG. 5—DETAILS OF SECTIONAL MAT SURFACE.

In any system of stationary jets it is extremely difficult to obtain uniform distribution of water over the entire tower at different rates of flow. With the slotted pipes, it is an easy matter to open or close the slots so as to distribute uniformly, and as they are laid horizontally this adjustment is permanent. It is also easy to free the laterals from foreign matter, as is not the case with jets.

THE EVAPORATED COOLER

In gas engine-work it is often necessary to economize water to the greatest possible extent. In an Arizona mining plant employing gas engines, where the mine water was so foul and acid as to prohibit entirely its use for cooling jackets an evaporative cooler was recently constructed of ordinary hot water radiators arranged in series-parallel, with air forced over the surface by a motor-driven fan. The well-known counter-current system was employed, and the outfit was fairly efficient, the jacket water being cooled 15 degrees with a power consumption of 5 per cent. of the output of the engine.

It occurs to the author that by keeping the radiating surface continually wet the effect of evaporation, as well as the convection, might be utilized in cooling. The foul mine water may sometimes be used for this purpose without contaminating the jacket circulation. With an expendi-

*In this plant the condensing system was not well adapted to economic working. Air and circulating pumps were direct-coupled, making it impossible to control the tower water separately from the condensation. There was considerable air in the system from a long run of exhaust piping; and with no dry-air pumps, a vacuum of 24 inches was normal practice. But the condenser was operated with a temperature differential of 47 degrees, so that with an efficient condenser, a vacuum of 28 inches might have been obtained with the same tower performance, 16 degrees cooling, 71 degrees cold well.

ture of 2¾ per cent. in evaporation an increase of 24 per cent. in cooling would be obtained, assuming the air entering and leaving to be fully saturated. This system has been attempted in connection with steam condensers, but apparently without much success. The principle seems entirely logical, but the difficulty of maintaining tight joints with thin-walled tubes of sufficient diameter to permit of the passage of the proper amount of air, would seriously detract from the effectiveness of this apparatus by reason of air leakage. The low vacuum shown during tests of such apparatus largely confirms this supposition. For gas power plants, however, the type seems admirably suited.

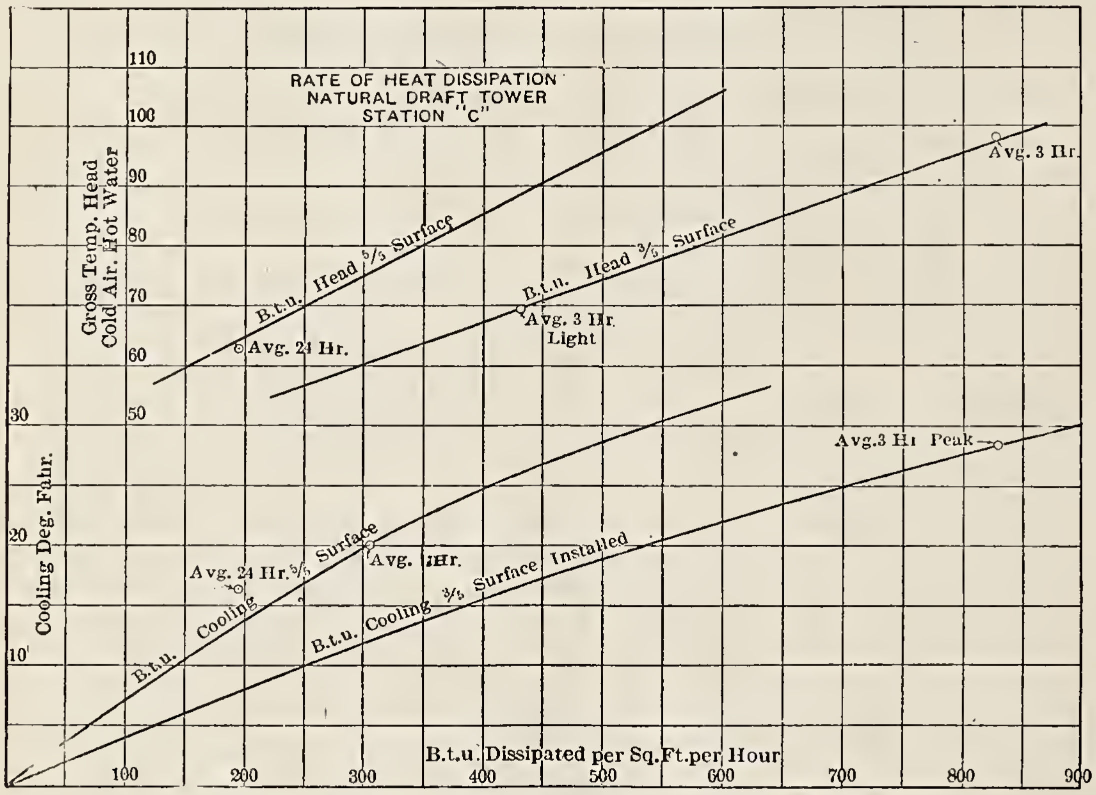


Fig. 8—RATE OF HEAT DISSIPATION OF THE DETROIT TOWER

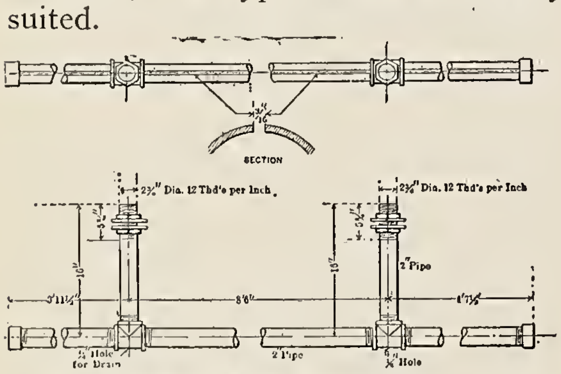


Fig. 7—DETAILS OF DISTRIBUTING PIPES

STANDARDS OF DESIGN

The cooling tower should be designed with the same flexibility as other good power plant apparatus, as regards capacity under various conditions of operation; it is subject to the same peak-loads as the prime mover. As a matter of fact, relatively more heat must be abstracted by the tower during peaks, owing to the higher steam consumption of a steam engine per horsepower-hour on overloads.

The problem of maximum capacity in cooling towers involves a condition of peak-load existing only 5 per cent. of the time, and high temperature only 8 per cent. of the time. Moreover, these maximum demands will not generally occur at the *same hours* of the day. In the example cited in the early part of this paper and illustrated by Fig. 1, 5 degrees difference in the condenser, the maximum permissible air temperature would be 81 degrees; the more efficient the condenser, the higher the allowable air temperature. Is it, therefore, good engineering to design a cooling tower installation with a vacuum-producing capacity *large enough for any and all emergencies;* or, on the other hand, to provide auxiliary means for assisting during these brief periods of maximum demand, while keeping the proportions of the tower within reasonable limits for normal operation? Might not even a considerable impairment of vacuum under the most unfavorable operation be better tolerated than the increased expense of equipment suited to maximum demand?

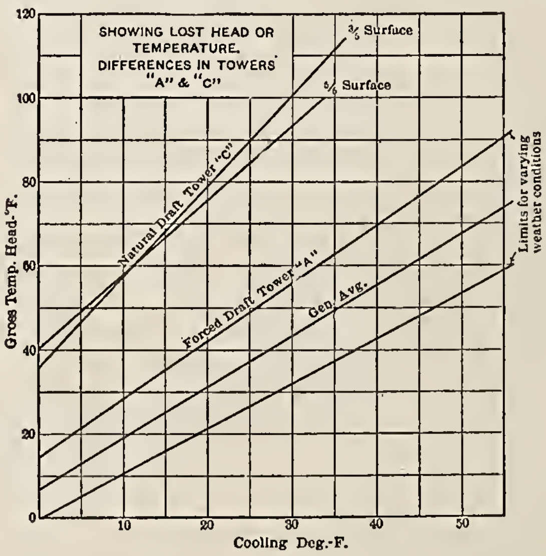


Fig. 9—LOST HEAD OF NATURAL AND FORCED DRAFT TOWERS

This, of course, applies particularly to natural-draft towers. Flexibility already exists in the forced-draft tower through the speeding of the fans; but even here there are some drawbacks, owing to the high velocities already employed for normal working. Any large increase in the velocity of the fan may seriously disturb the uniformity of air distribution over the tower surface and give rise to eddies destructive to efficiency. That this condition exists is very plainly shown by a survey of the discharge velocity by means of an anemometer. Examination of one defective installation by this method revealed the fact that fully one-third of the area was practically ineffective and that the reverse currents actually took place in some parts. The air distribution problem is exceedingly important, and more so in the forced-draft than in the natural-draft tower, where low velocities favor uniformity.

TABLE I COMPARATIVE DATA, DETROIT EDISON TOWERS.

Type.	Forced Draft, Station A.		Natural Draft, Station C.	
Rated engine, i.h.p	1,500		900	
Cooling surface, sq. ft.	34,780		24,500	
Surface per h.p	23.2		27.2	
Space occupied, cu. ft.	7,064		10.850	
Space occupied, sq. ft.	175		200	
Cost complete	$3,900		$1.350	
Cost per h.p	$2.60		$1.5	
Auxiliaries, e.h.p.	13		..	
Dimensions.				
	ft.	in.	ft.	in.
Delivery pipe above ground	29	0	35	8
Height over all	40	6	53	9
Height mat section	17	0	25	0
Height stack	12	6	18	1
Height outlet	10	10	9	0
Diameter tower	14	10	16	0
Diameter fan	9	3	..	..

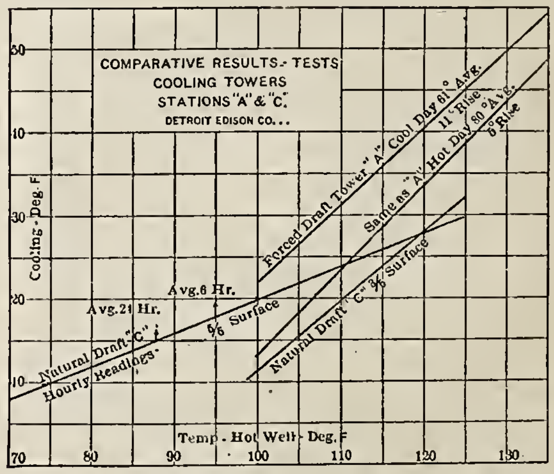


Fig. 10—COMPARATIVE RESULTS, NATURAL AND FORCED DRAFT TOWER

"BOOSTER" TYPE OF TOWER

The natural-draft tower is of itself ill adapted for operating with a fixed temperature head. It thrives on the weakness of the condensing system. The lower the vacuum, the better the tower works, because of the increase in temperature head. And as this is clearly a problem of chimney design, the only way out of the difficulty is apparently by some method of auxiliary draft. As the specific heat of air is about 0.23, it is

TABLE II. TEST OF NATURAL-DRAFT COOLING TOWER, DETROIT.
Complete, Three-fifths Surface Installed.

Time.	Air.	Hot well.* 3	Cold well. 4	Water cooling. 5	Total heat head. 6	Tower water, lbs. per hr. 7	Heat dissipated B.T.U. lbs. per hr. 8	Heat per sq. ft. cooling surface pr. hr. 9	Circulating water per sq. ft., lb. per hr. 10	Load. kw. 11
12 noon	34	102	89	13	68	375,000	4 880,000	332	25	270
1:30	35	106.5	90	16.5	71.5	{375,000	6,108,000	415	24.8	315
						{370,200				290
2:30 }	35	106.5	87.5	19	71.5	375.000	7,120,000	484	25	315
3:30	35	113	88.5	24.5	78	375,000	9,000,000	613	25	350
4:30	32.5	100	84	16	67.5	399,000	6,384,000	434	26.6	365
5:00	28.5	103.5	88	15.5	75	445,500	6,900,000	470	29.7	485
4:00	26	125	94	31	99	417,000	12,930,000	880	27.8	655
7:00	24	121	94	27	97	427,000	11,532,000	785	27.4	570
8·00]	24	123	94.5	28.5	99	427,000	12,174,000	827	27.4	600

*Assuming a more efficient condenser, say 10 deg. difference, the probable vacuum would be 24 deg. to 27.5 deg. This condenser actually operated at 40 deg. to 50 deg. difference.
Total heat head = air heating + lost head.
Difference due to rapid change in load.

TABLE III. RESULTS OF TEST OF NATURAL-DRAFT TOWER, DETROIT.
Complete, Five-fifths Surface Installed.

		A. M.	P. M.		Average.
Engines:	Twl 400 I. H. P. 300 kilowatt MacIntosh & Seymour tandem compound engincs, overhung generators.				
Condensers:	Worthington surface (admiralty type), 1,600 square feet reciprocating wet-air pump and circulating pump.				
Tower:	Wood mat construction, 24,500 square feet evaporating surface, exclusive of shell.				
Test:	March 15 to 14, 1901, 4 p. m. to 4 p. m., 24 hours.				
Weather:	Barometer (abs.) min.	30.22	30.77	30.14	30.27
	Temperature air, deg. Fahr.	18.5	25	30	25
	Relative humidity, per cent	76	82	58	72
Load:	600 kilowatt max. to 50 kilowatt min.—Average				244.9 kilowatt
	Engine efficiency = 92.5 = 875 I. H. P. max.—Average				354.8 I. H. P.
Steam:	Weight of condensed steam per hour, pounds				5,910.6
	Temperature exhaust steam, deg. Fahr.				134.38
	Temperature clndensed steam, deg. Fahr.				108.78
	Weight of steam per hour, max. load pounds				13,500
	Vacuum (abs.) 25 to 19, average about				22
	Vacuum corresponding to temperature exhaust steam, ins.				25
	Vacuum possible with good condenser (10 deg. difference)				28
Water:	Circulated per hour pounds				293,536
	Temperature hot well, average deg. Fahr.				87 50
	Temperature cold well, average deg. Fahr.				71.27
	Vaporization loss per hour pounds				5,970
Results:	Condenser surface per kilowatt, square feet				2.66
	Steam per kilowatt hour pounds				24.3
	Steam per I. H. P. hour, pounds				16.66
	Circulating water per pound of steam, pounds				49.6
	Steam per square foot condenser surface per hour, pounds				3.7
	Circulating water per square foot tower surface, pounds				12.0
	Difference in temperature between exhaust steam and discharge deg. Fahr.				47
Cooling:	Max. 20 deg., min. 3 deg.—5 deg. Average				16.23
	Heat dissipated per hour, B. T. U.				4,769,000
	Heat per square foot tower surface, B. T. U.				195
	Heat per square foot per 100 pounds water, B. T. U.				0.665
Evaporation:	Circulating water, per cent				2.03
	Engine steam, per cent				101
Tower:	Surface per kilowatt (average load 245 kilowatts), square feet				100
	Surface per kilowatt (max. load 600 kilowatts), square foot				408
	Surface per 1,000 pounds steam max. load, square foot				1.82
	Surface per 1,000 pounds steam average load, square foot				4.14
	Surface per 1,000 pounds circulating water per deg. max. cooling, square foot				5.22

evident that an increase of 25 per cent. in heat dissipation would require roughly double this increase in quantity of air, in order to maintain the same temperature conditions. This, however, is well within the capacity of a comparatively small fan auxiliary.

There are two methods of accomplishing this result: (a) By locating in the stack an induced-draft fan which normally remains idle. (b) By installing at the base of the tower a forced-draft system so designed as to supplement the natural draft without causing a back flow. The second suggested arrangement is crudely shown in Fig. 11. The auxiliary air is delivered to the tower through four "L"-nozzles supplied from a concrete duct surrounding the base of the tower. With this arrangement, the natural draft under the base of the tower might tend to be reversed, owing to the back pressure resulting from the blast. It is believed, however, that with a fairly open mat structure, such as has been described above, the introduction of four auxiliary blast ducts would serve only to entrain more air and further assist the tower in the absorption of heat.

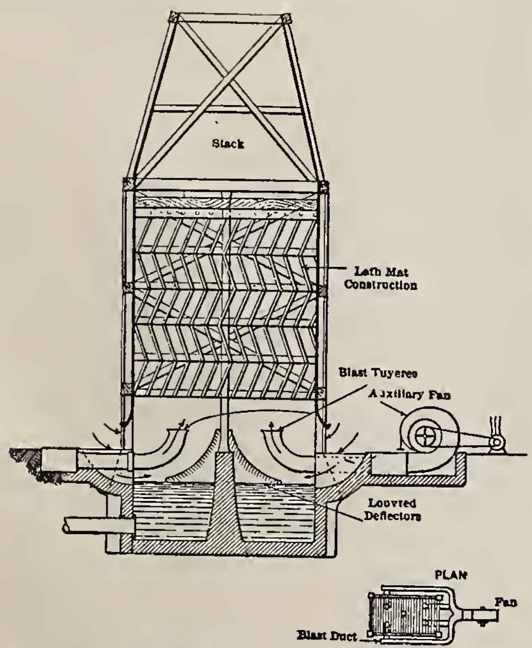


Fig. 11—PROPOSED COMBINATION TOWER WITH NATURAL AND FORCED DRAFT

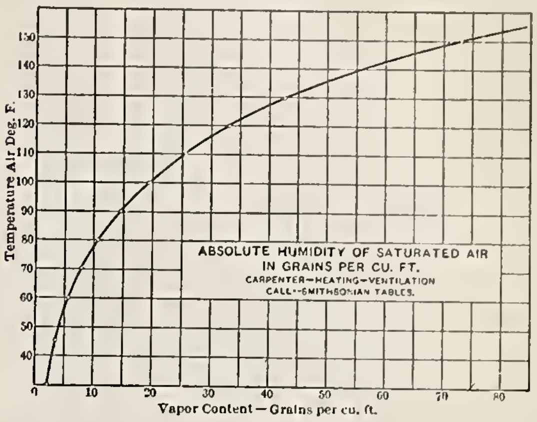


Fig. 12—VAPOR CONTENT OF AIR AT VARIOUS TEMPERATURES

Of the two systems, the former has the advantage of being already put in practice. However, there is to be said in favor of the latter that no working parts, such as fan bearings, belt transmission, etc., are in the current of vapor; and with a tower operated intermittently, corrosion is an important matter. Furthermore, this system lends itself more readily to a square or rectangular shaped tower, which may be desirable in large sizes.

TABLE IV. OPERATING DATA, OPEN-SCREEN TOWERS.

Mt. Whitney Power Co., Visalia, Cal.

Tower designed for 1,500-2,000 kilowatt at 27 inches vacuum.	
Horizontal screen surface, square feet	9,550
Circulating water handled, gallons per hour	1,720,000
Rate of circulation, pounds per square foot per hour	1,500
Dimensions, feet	30 by 47 by 15 high
10 tiers galvanized iron screen	5 mesh per inch.
Cost of tower, including concrete form	$2,000
Observations, October 23, 1906.	
Maximum load carried, 5:20 p. m., kilowatt	1,130
Temperature atmosphere, deg. Fahr.	55
Depression, wet bulb thermometer, degrees	8.5
Relative humidity, 50 per cent, absolute, grains per cubic foot	2.35
Temperature incoming hot water, deg. Fahr.	110
Temperature outgoing cold water, deg. Fahr.	100
Cooling, deg. Fahr. (minimum for day)	10
Vacuum carried (ref. 30-in. barometer), inches mercury	26.6
Difference between temperature steam and condenser discharge.	
Possible vacuum (10 deg. difference in condenser).	
Maximum cooling for day (730 kilowatts), deg. Fahr.	16

Data from Hunt, Mirk & Co., Engineers, San Francisco, Cal.

The Western Electrical and Gas Directory

The 1910 edition of "Blanchfield's Western Electrical and Gas Directory" contains the names of 1345 companies and individuals in Arizona, California, Idaho, Nevada, Oregon, Washington, British Columbia and the Hawaiian Islands.

Electrical installations foot up a total of 920,939 kw., normal rating, providing a value of 1,151,174 electrical horsepower. In addition to which there is projected 383,600 h.p., from water and steam.

The relative quantities of Water-, Gas- (or distillate) and Steam-generated electric power are given below. Included under the head of "Steam" is 106,530 kw., normal rating, produced by steam turbines; of which amount 6650 kw. is in Arizona, 57,160 in California, 1295 in Idaho, 1150 in Nevada, 7000 in Oregon, 24,775 in Washington, 2250 kw. in the Hawaiian Islands.

	Electric Power Generation, Kws. Water	Steam	Gas
Arizona	9,025	16,056	1,290
California	254,254	287,622	13,301
Nevada	14,250	3,957	105
Oregon	47,170	29,745	50
Washington	106,070	57,714	120
Idaho	13,284	5,545	....
British Columbia	48,255	3,492	....
Hawaiian Islands	4,700	4,934	....
Totals	497,008	409,067	14,866

The Effect of Electrical Operation on the Permanent-Way Maintenance of Railways

By CHARLES AUGUSTUS HARRISON, D. Sc., M. Inst. C. E.

When it was decided in 1903 to equip the Tynemouth branches of the North Eastern Railway for electrical operation, no information was available as to the increased work and cost involved by the electrical equipment of the permanent way, the experience obtained on American railways not being directly comparable with the conditions existing on English systems. There was consequently some doubt as to the magnitude of the additional work which would be thrown on to the maintenance staff, first, by the upkeep of the electrical equipment itself, and, secondly, by the increased difficulty of maintaining the permanent way due to the presence of the "live" rails and the larger number of trains. But after five years' experience, it is possible to speak with some degree of assurance as to both the difficulties and the cost. The conditions of the electrical train service now running and the steam service it displaced are, however, so different that some detailed description of them becomes

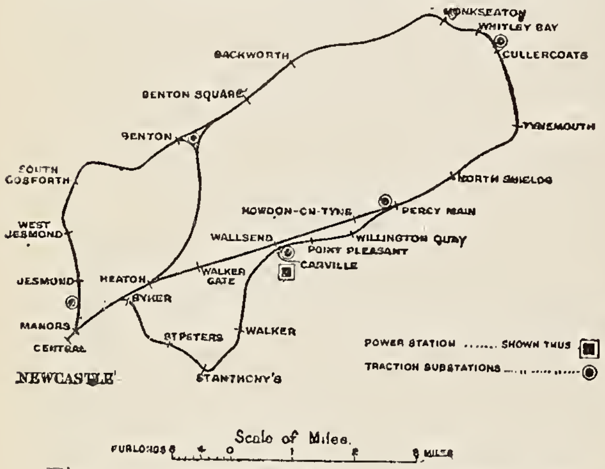


Fig. 1.—NEWCASTLE AND TYNEMOUTH BRANCHES, NORTH EASTERN RAILWAY

necessary before dealing with the main point.*

THE ELECTRICAL EQUIPMENT

The equipment, with the exception of the coach-bodies, which were built at the Company's York works, was carried out to the specifications and under the supervision of the Company's consulting electrical engineer, Mr. Charles H. Merz, M. Inst. C. E., and the following particulars indicate the general scheme of conversion:

The branches electrified are shown in the plan, Fig. 1, and comprise a route 29.5 miles long, the equivalent single-track mileage, including sidings, being 75 miles; the average distance between station stops is 1¼ mile. The equipment of the track is on the now familiar conductor-rail system, in which electrical energy at 600 volts is supplied to a steel rail laid along the track and is thence conveyed to the trains by contact-shoes mounted on the trucks and making sliding contact with the conductor rail. The design of shoe in use is shown in Fig. 2, which also illustrates the arrangements provided for fixing the shoe clear of the conductor rail when this is desired.

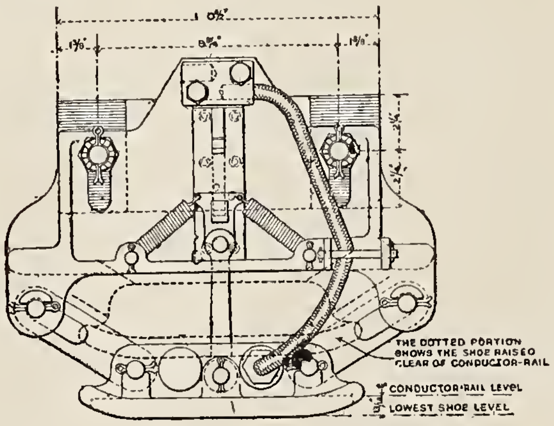


Fig. 2.—CONTACT-SHOE

The return path for the current after passing through the train-motors is through the wheels to the running-track rails, which, as in the case of the conductor rails, have been bonded at each joint to render them electrically continuous. The type of bond and the method of fixing it are shown in Fig. 3.

Where level crossings or special track work render it necessary to break the continuity of the conductor rail, the gaps thus formed are bridged by insulated copper cable, laid underground.

The normal position of the conductor rail is in the 6-ft. way at a horizontal distance of 1 ft. 7¼ in. from the gauge line of the nearest track rail. This is the standard gauge adopted in 1903 by the English railway companies, except on tube and tunnel systems, where a smaller dimension is worked to on account of structural considerations. The rail is mounted on insulators and raised so that the table of the conductor rail is 3¼ in. above that of the track rail. Between station platforms and at points where there is necessity for the operating staff to cross the tracks, accidental contact with the conductor rail is provided against by protection boards erected vertically on either side of the live rail, from which they are suspended by iron brackets. The fixing of these boards is so arranged that they can be easily lifted from the brackets for cleaning insulators, etc.

In order to prevent "creeping" of the longer lengths of the conductor rail on the insulators, and the consequent straining of the electrical connections at cable terminals; anchorages are provided as shown in Fig. 4.

The conductor rail is sectioned for convenience at feeding and intermediate points, and also at all junctions. The sectioning switch-gear is erected in the signal-cabins and is directly under the charge of the signalmen, who are in telephonic communication with the sub-stations and power-station. Sidings which are not continuously in use are provided with sectioning switches, erected in cast-iron pillars mounted alongside the track and under the care of the signalman or shunter, as may be most convenient. In addition, provision was made, by a specially designed cable terminal, to afford ready and convenient means for more local sectioning wherever the continuity of the conductor rail was interrupted, i. e., at level crossings, junctions, etc. The design of this terminal, which has been found very useful in practice, is shown in Figs. 5; the live terminals being protected against accidental contact by an enclosing pot-ware cap.

The sub-stations are five in number and are situated as shown on the plan (Fig. 1), which also shows the position of the Carville generating station of the Newcastle-upon-Tyne Electric Supply Company. From here power is supplied in bulk to the railway company at the sub-stations as three-phase current at 5,750 volts. The sub-stations are equipped with static transformers and rotary converters for transforming the bulk supply to the 600 volts continuous-current supply to the conductor rail.

The rolling stock consists of 106

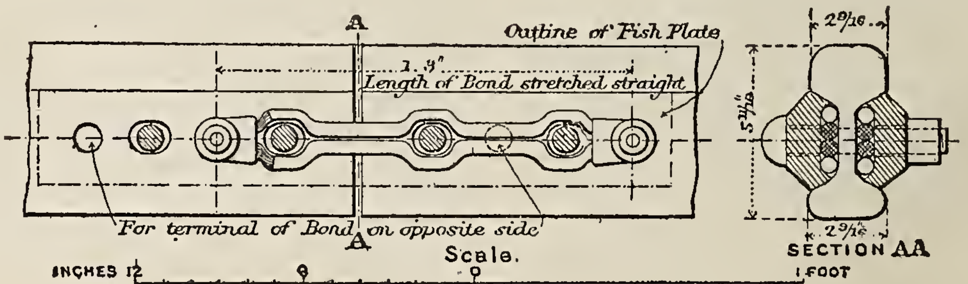


Fig. 3.—BONDED JOINT ON TRACK-RAIL

*Institution of Elect. Eng.

passenger coaches of the open-corridor type, each with a seating capacity of sixty. Of these coaches 62 are motor coaches and 44 are trailer coaches, all the motor coaches being provided with driving ends and collector gear, while some only of the trailer coaches are equipped for driving from. Each motor coach is capable of performing the schedule speed when handling one trailer coach, and the trains may be made up of any number of coaches driven from any driving end on the train so long as this proportion is not exceeded. In practice the trains vary

	Steam.	Electric
Average schedule-speed (miles per hour)	16.7	20
Increased speed of electric trains (per cent.)	..	19
Acceleration (miles per hour per second)	0.5	0.75
Maximum train-service per hour	10	15
Normal " " " "	1	4
Train-miles per annum	600,000	1,199,729
Car- " " "	3,900,000	3,772,601
Ton- " " "	115,200,000	104,600,000
Average number of cars per train	6.5	3.14
Maximum number of cars per train	7	9
Average weight of train	192 tons	87.2 tons
Passenger-coaches in use (normal service)	84	85
Locomotives in use (normal service(	14	....

from one to nine coaches, the latter being the limit of the station platforms.

For goods, parcels and fish traffic three motor parcels vans and two 50-ton locomotives are employed; the parcels vans are specially designed for running the fish and parcels traffic between the passenger trains without holding them up, and the locomotives for dealing with the heavy goods traffic (300-ton trains) between the quayside and the Manors Station up a

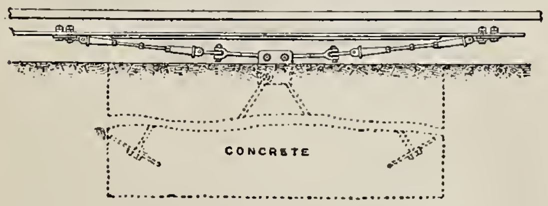


Fig. 4.—ANCHORAGE FOR CONDUCTING-RAIL

tunnel grade of 1 in 27. In addition to the parcels traffic, the motor vans are used to haul heavy workmen's trains, which are made up of ordinary steam carriage stock retained for the purpose.

COMPARISON OF WORKING RESULTS UNDER STEAM AND ELECTRICITY

The above table compares the train service under steam and electrical working, and it will be noticed that, although the train-mileage has been nearly doubled, both the car-mileage and the ton-mileage are slightly less under the new conditions.

It was not to be expected that the upkeep of the electrical equipment could be dealt with without some increase in the maintenance costs, but the additional cost has not proved to be a heavy one; and that the increase is not larger is due to the ease with which the working staff undertook the electrical equipment, only two special hands being taken on, namely, cable-jointers. All repair and renewal connected with the electrical equipment is carried out under the permanent-way inspectors by the ordinary track gangs, special provision being made, by the use of insulated tools and working regulations, to avoid danger to the men by shock. Very little trouble has resulted from working on the live rail, and in all cases it has been caused by a departure from the regulations.

The comparative accelerations of a steam and an electric train, each consisting of five coaches, is shown by the curves in Fig. 6, which represents the results of some tests recently made. The figure attained by the electric shock under normal working conditions is 0.75 mile per hr. per sec. as compared with 0.50 mile per hr. per sec. for the steam trains; the figure for the electric stock is constant for any size of trains, but would be decreased with an additional number of coaches in the case of the steam train.

Driving-Wheels.—The effect of the smaller driving-wheel (3 ft. as compared with 5 ft. 6 in. in diameter) is shown by a diagram (Figs. 7), in which the two wheels and the positions with regard to intersections of a crossing are indicated. The additional hammer of the smaller wheel when crossing the intersecting gap, added to the non-spring-borne weight of the motors, has a marked influence on the life of a crossing. Instances have occurred of crossings, which under steam conditions would have lasted nine years, requiring renewal at the end of five years. The actual effect on points and crossings is shown on the sketches of work taken out after five years under conditions of electrical working (Figs. 8 and 9).

To meet the new conditions of wear, especially on curves and at crossings, Sandberg and manganese-steel rails have been installed, and it remains to be proved whether the additional cost involved by these arrangements will be justified by the increase in life obtained.

So far as the straight track is concerned, no definite opinion can be formed at this date as to the increase of wear, if any, under the new conditions; it is certain, however, that the effect is not very marked.

Ballasting.—With a regular service of trains every 15 minutes in each direction, the difficulties of maintenance were naturally increased, and it became desirable to adopt a type of ballast requiring less attention than the ash ballast with which the branches were laid down. After experimental lengths had been ballasted with various classes of stone, it was eventually decided to adopt a hard limestone with an outside limit in size of 2 in., and this is now laid on the greater portion of the branches. The fact that the stone has a high insulation resistance as compared with the ash ballast was also a factor in coming to this decision.

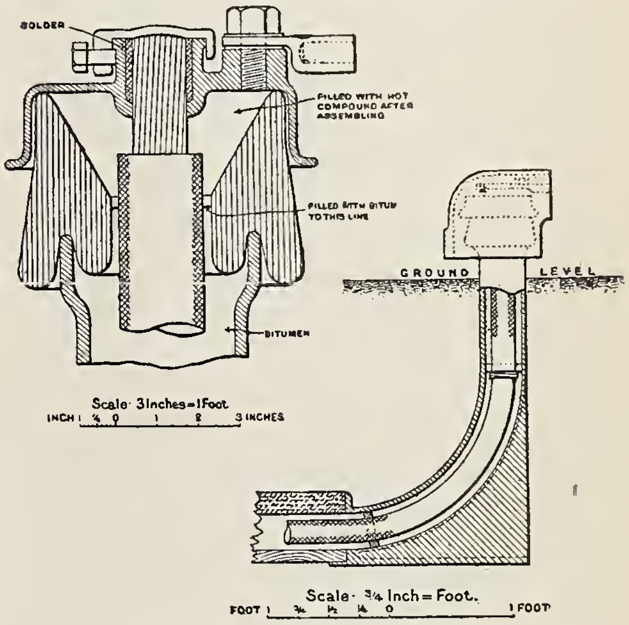


Fig. 5.—TRACK-CABLE TERMINAL

MAINTENANCE OF ELECTRICAL EQUIPMENT

Inspection.—No special provision is made for general inspection, this being attended to by the lengthsmen as part of their duty. In the event of a damaged insulator being detected, it is reported for renewal; if damaged so badly as to be likely to cause trouble, it is removed clear of the conductor rail as a temporary measure, the spacing of the insulators being such that the intermediate ones can be temporarily removed without undue sagging of the rail or stress on the remaining insulators.

At definite intervals special inspections are made of insulators, bonds and all electrical connections, including the switchgear. The intervals between inspections vary—those for the switchgear and connections being made monthly, while inspections of the

Item	Loss in per cent. per annum.
Insulators	2.0
Third rail	1.75 to 2.0*
Track-bonds	0.5
Third-rail bonds	0.5
Low-tension cable	Three lengths renewed in 5 years.
Switch-gear	" switches " " " "

* Before painting was commenced.

track bonds and third-rail bonds are made every two years.

Snow and Ice.—One of the anticipated difficulties in connection with the maintenance was the possible accumulation of snow and ice on the contact surface of the conductor rail, and the formation of a film of insulating material between the rail and the contact shoes on the coaches. It is a condition of working which has been found

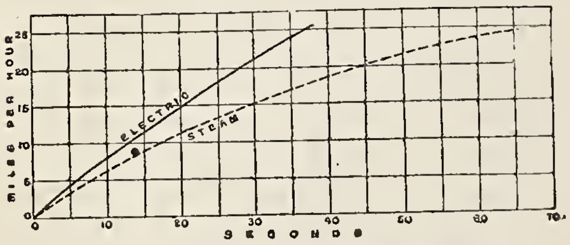


Fig. 6.—ACCELERATION OF TRAINS

very severe on American systems, and is doubtless largely responsible for the adoption there of various forms of over-rail protection, which is expensive both to install and to maintain. In Newcastle, however, the difficulty has been successfully met by the use of a special ice-scraper, mounted on the truck beam carrying the contact shoes. The scraper, which is shown in Figs. 10, consists of a number of steel plates arranged vertically with their edges in contact with the rail table. These plates, which are arranged diagonally across the longitudinal centre-line of the rail, are cast solid in a block of cast iron, and the edges are pressed against the contact surface of the rail by a spring pressure of about 50 lb. Normally the weather conditions do not require the use of the scrapers, and they are raised by hand clear of the rail. During bad weather, however, the coaches are sent out of the sheds with the scrapers

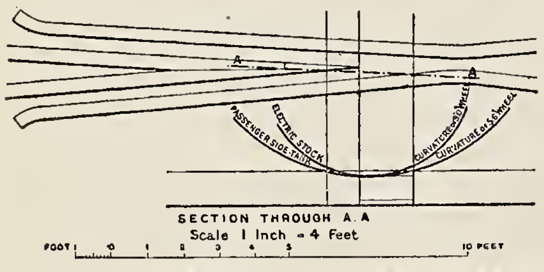


Fig. 7.—COMPARATIVE CURVATURE OF WHEELS

screwed down, and when necessary at other times the motormen on the trains put them to work. If between the hours of 1 A. M. and 5 A. M. a fall of snow takes place or falling rain is likely to freeze on the rail surface, a special coach fitted with scrapers is continuously run in order to keep the line open.

Danger from Shock.—In five years' working there has been no case of fatal shock to employees, while even cases of bad shock are exceedingly rare. Without exception the regrettable fatalities that have occurred on the system have been the result of trespass by unauthorized persons, which on any railway with a frequent service of fast trains involves serious danger. Every possible precaution is taken, by the free distribution of insulated tools, rubber gloves and mats, and by protective regulations, to avoid shocks, and the comparative immunity from trouble has no doubt been largely due to those precautions.

Insulators.—The original equipment of the line included conductor-rail insulators of reconstructed granite, which at that time was the standard practice in the United States. The total number installed was approximately 40,000, and it was not surprising that among this quantity

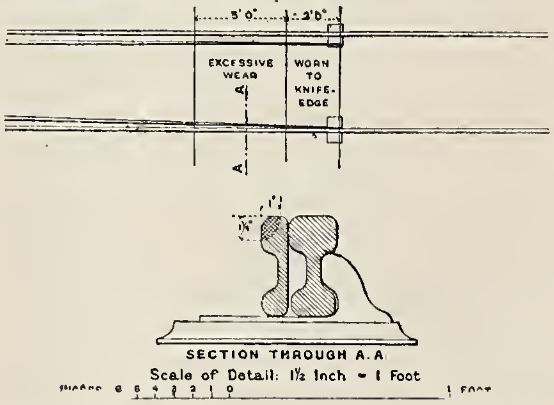


Fig. 8.—DIAGRAM ILLUSTRATING THE EXCESSIVE WEAR ON A SWITCH

and during the early days of working a number of faulty insulators had to be weeded out. Since that time, however, numerous experiments have been made with various designs and materials, with the result that a porcelain petticoated type has now been standardized which will, by its longer life and efficiency, amply compensate for its higher first cost as compared with reconstructed granite and pot-ware. A sketch of one form of this pattern as modified by the makers for constructional purposes is shown at D in Fig. 11, together with other forms of insulator in use.

Conductor Rail.—The loss by corrosion of the conductor rail has been between 1¾ and 2 per cent. per annum, and measures to prevent or, at any rate, to retard this action were necessary. Accordingly the rail throughout has now been scraped and painted with a heavy oxide paint.

Renewals.—The system of inspection adopted enables a close estimate to be made of the annual renewals, a summary of which is given in the following table. It is anticipated that the loss in insulators and rail will decrease, while the bond failures will probably increase.

The return for switchgear and cables, and also to a considerable extent for insulators, is not renewal in the sense of depreciation, but is occasioned by exterior causes; as, for instance, a train derailment, which in one case destroyed insulators and cable terminals over a distance of ¼ mile.

Annual Costs.—With regard to the cost of maintaining the electrical equipment of the track, while it is not possible to give a figure that will be applicable to all lines and conditions of working, a general figure, the result of experience, may be interesting. Assuming, as in the North Eastern Railway case, that no special staff is organized to deal with the work—that is, it is dealt with by the permanent-way inspectors—and that the equipment is laid down with proper regard for the service to be met, £50 per annum per mile of single track should cover all likely contingencies.

It is more difficult to ascertain the cost of the increased wear on crossings, curves, etc., nor until experience has been considerably extended could any assumption be justified. In any case it would not be fair to debit electrical working with the wear due to the rapid acceleration obtained, as

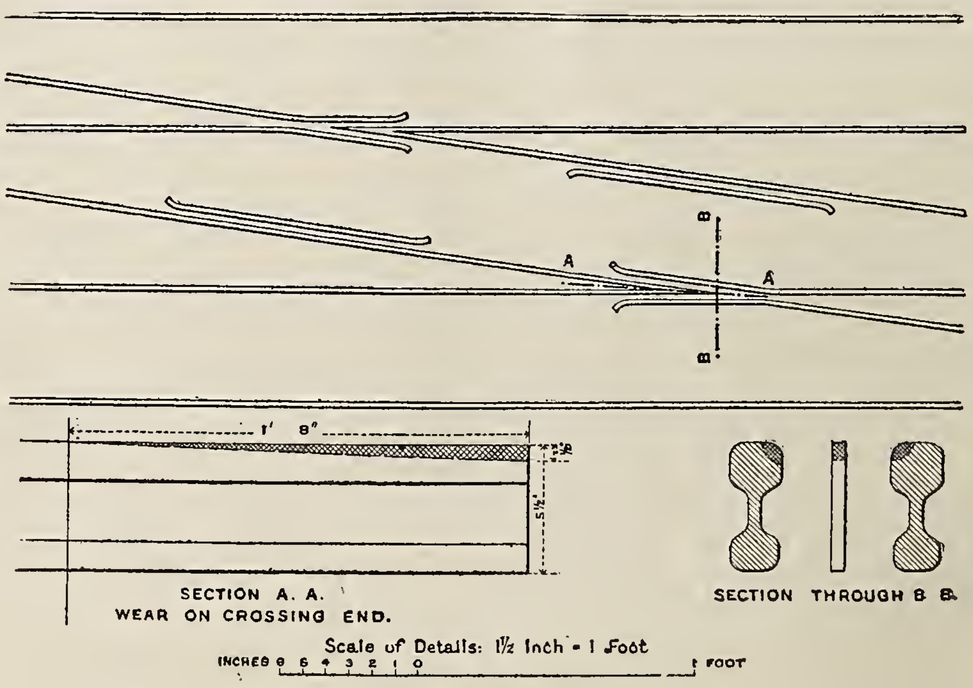


Fig. 9.—DIAGRAM ILLUSTRATING THE EXCESSIVE WEAR AT A CROSSOVER ROAD

without this acceleration the increased schedule speed would not be possible, and steam locomotives for this acceleration would, owing to the increased weights, be equally, if not more, severe on the track.

CONCLUSION

Although the foregoing remarks would indicate some increase in the

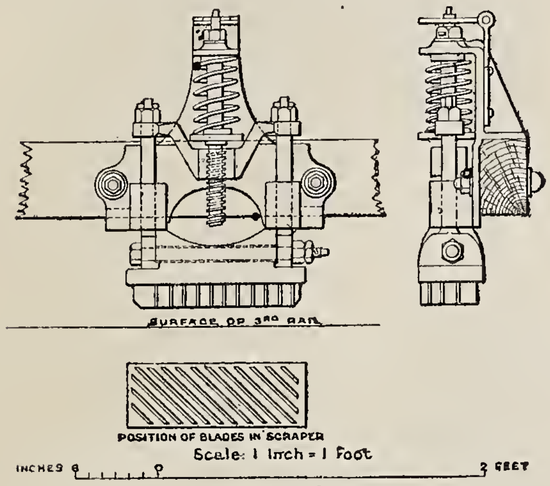


Fig. 10.—ICE-SCRAPER

cost of permanent-way maintenance by the introduction of electrical working, with its consequent improved traffic facilities beyond what was practically possible with steam trains, it must be borne in mind that substantial economies in trackwork have been rendered possible in other directions. Since the inauguration of electrical working the passenger load has steadily increased, and the present volume could not be dealt with by any other method without substantial increase of terminal accommodation.

During the busy hour in the evening 15 trains are dispatched from two terminal platforms at the central station, while during the "rush" traffic five trains are dispatched at 1-

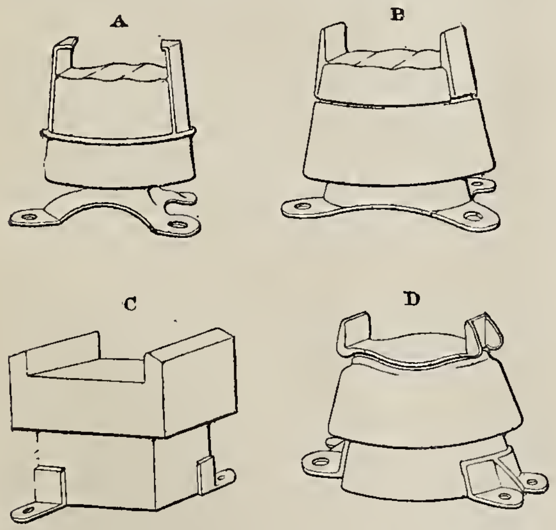


Fig. 11.—PRINCIPAL TYPES OF INSULATOR IN USE

minute intervals, each carrying upward of 500 passengers. In the mornings, when traffic is even more concentrated, trains up to 550 feet long are employed—the length of the train on the multiple-unit system of train working being only limited in practice by the lengths of the platforms. During the summer the holiday traffic between Newcastle and the coast is very heavy, upward of 100,000 passengers being dealt with during the day. The city-ward traffic in the evening at these times is largely concentrated into less than three hours, and whereas the present train service deals with such loads with ease, the superseded steam trains were frequently working until 2 A. M. after a bank holiday.

The electrical equipment was carried out without at all affecting the running of the steam trains, and the change-over was made during one night. The complete steam service was run up to the night of June 30, 1904, and the complete electrical service was put into use the following morning; it has been maintained without intermission from that date. Notwithstanding the fact that the number of local trains in and out of the Central has been practically doubled, the train- and signal-movements there have been reduced, and the same platform accommodation, which before had been cramped and required extension is now ample for all purposes. Further, the punctuality of the service has been greatly improved, and it is no exaggeration to say that the system is extremely popular, both with the travelling public and with the operating staff.

New Design of Engine to Produce Uniform Torque

To everyone familiar with the shape and meaning of a steam engine indicator card, it is evident that the thrust given to the piston by the steam varies considerably throughout the stroke. Thus, during admission, the pressure is maximum; after cut-off the pressure gradually falls and finally becomes negative at the end of the stroke, because the steam at the other side of the piston is being compressed. This means that instead of tending to push the crank pin forward the piston really pulls it back.

If the engine is a "simple" one—that is, has only one cylinder, it is evident that this varying force on the piston produces a fluctuating turning-force at the crank pin and, furthermore, on account of angularity of the connecting rod the force on the crank pin is by no means equal to the thrust on the piston. At the beginning of the stroke the force urging the piston forward is high, as pointed out above, but the force tending to turn the crank, or the tangential force, is extremely low, as the crank is only slightly off "dead center," and most of the thrust given by the piston is expended in pushing directly against the shaft bearing. These changes in tangential effort cause the speed of rotation to vary for different positions of the crank pin. In one-cylinder engines the only way to prevent these variations in speed from becoming excessive is to use a very heavy flywheel, which will store up energy when the thrust is high and give it up again when the thrust is low. The fact that the turning moment varies with the change of steam pressure in the cylinder, and at the same time with the angle that the connecting rod makes with the line of centers, renders it rather a complicated problem to foresee what the resultant tangential effort will be for any particular engine without careful computations.

One way to produce a more even turning moment is to connect several cylinders to a single crank shaft. This gives numerous impulses per revolution, and each being of the same intensity and occurring at equal intervals of time, produces a practically uniform turning effort, and also has the further advantage that for a given amount of work the thrusts given by the separate cylinders can be smaller than if all were delivered by one.

The following discussion relates more specifically to high-speed engines of medium size, such as are commonly used for driving lighting units in office buildings, apartment houses, hotels, etc. In isolated plants such as these one of the important requirements is to get as much power as possible on a square foot of floor space, and at the same time to have as low steam consumption as possible, for even where exhaust steam is used for heating purposes no one wants to throw away more steam than is necessary during the summer months when the engines exhaust to the atmosphere. The cross compound engine, while giving as good steam economy as any other type, occupies entirely too much floor space and is seldom used. The two types of engines which meet these conditions most satisfactorily are the angle and the tandem compound, but, as shown on page 339, the relative positions of the cylinders has a marked bearing on the performance of the engine.

In the tandem compound both pistons are on the same piston rod, one behind the other, and always move together. A little thought will show that as both pistons are always mov-

ing in the same direction, there will be an enormous thrust delivered at the beginning of the stroke when both are receiving maximum steam pressure. After the point of cut-off the steam expands in both cylinders, the thrust gradually falls off until it reaches zero and then becomes negative, due to high compression necessary with the high speed commonly used in connection with small-sized units.

Thus it is seen with this construction the pressures on both pistons, whether positive or negative, are always added together, the pistons given a violent kick at the beginning of each stroke, and are, in fact, thrown back and forth more like a shuttle; therefore, unless an immense fly-wheel is used, anything like a uniform turning moment is impossible.

In the angle-type engine, illustrated herewith, the low-pressure cylinder is placed vertically on the same bed-plate with the high pressure and exactly at 90 degrees to it. In this case it will be seen that the maximum thrust, due to the admission of steam to the low-pressure cylinder, does not occur until after the high-pressure cylinder has finished half its stroke, and the pressure in it is rapidly falling off. Then maximum pressure occurs in the low-pressure cylinder, and after it has finished half of the stroke, steam is again admitted to the other side of the high-pressure piston, and so on. It will thus be seen that instead of the two maximum thrusts occurring at the same time, there are four which follow one another with uniform regularity. This arrangement tends to produce a more uniform turning force, and the following diagrams have been worked out accurately to show how the force actually varies in the two cases.

The four indicator cards in Fig. 1 are from a compound engine, and the same cards were used in figuring out both curves in Fig. 2.

The positions of the cards, as shown in Fig. 1, represent the events as they occur in a tandem engine. Curve A was plotted from the cards in this position. The ordinates for each card were taken for every 15 degrees turned through by the crank and multiplied by the corresponding piston areas. The sum of these two gives actual pounds thrust on the piston. This was then corrected for angularity of piston rod, so that of the total thrust, only that portion was plotted which tends to push the pin in a circular path.

It is seen that, with the tandem engine, the tangential force delivered to the crank-pin at first rises very rapidly, then quickly falls to zero, and when the crank has turned through an angle of approximately 150 degrees, or is very nearly at the end of one stroke, the force becomes negative. This is due to the fact that the steam pressure resulting from expansion is rapidly becoming lower, while the steam on the other side of both pistons is being compressed at the same time; hence, at this point, instead of the pistons tending to drive the pin forward, they become a drag and have to be carried to the end of the stroke by the inertia stored up in the fly-wheel.

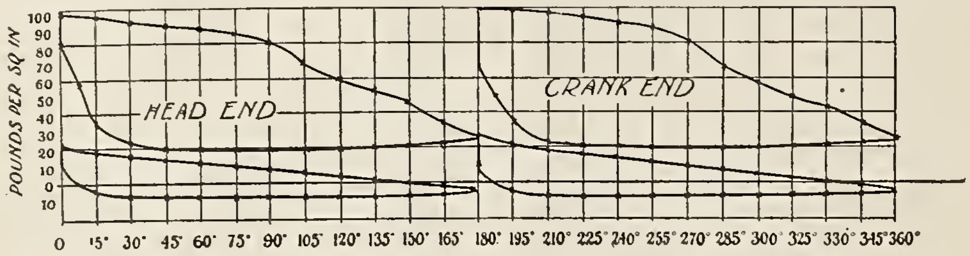


Fig. 1—INDICATOR CARDS FROM WHICH BOTH CRANK EFFORT CURVES SHOWN BELOW WERE CALCULATED

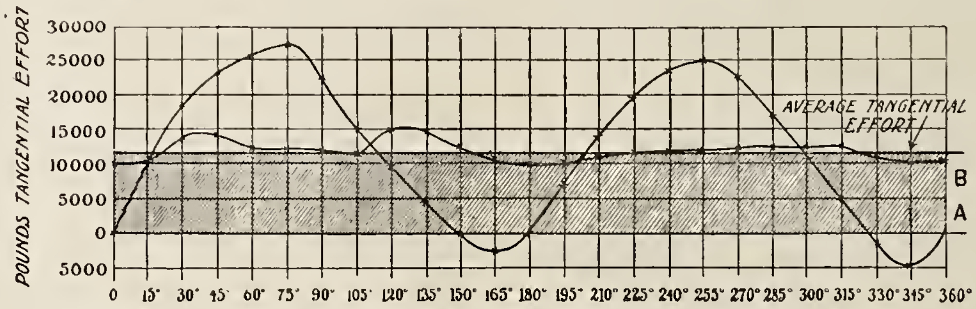


Fig. 2—CRANK EFFORT DIAGRAMS: A—FOR TANDEM COMPOUND ENGINES; B—FOR ANGLE COMPOUND ENGINE. BOTH ENGINES DELIVERING THE SAME AMOUNT OF ENERGY, REPRESENTED BY THE SHADED AREA

Curve B shows the crank effort from an American Ball angle-compound engine. Here the low-pressure cards are moved forward 90 degrees, and the tangential efforts were figured out separately for each cylinder for every 15 degrees, and then added together. The remarkable thing about this curve is its extreme "flatness," which shows how small the variation in turning moment is in this engine.

The piston areas, points of cut-off and division of the load have been carefully worked out with a view of producing this uniform torque.

In these curves the modifying effects of friction and inertia of reciprocating parts have been neglected in order not to complicate the problem; but had the effects of inertia been taken into consideration, the results would have shown up still more favorably to the angle-compound engine, as the masses moving in the same direction are smaller, and the fact that they are separated 90 degrees allows of perfect balancing, which is impossible with either the tandem or cross-compound construction.

The line of average tangential effort was located in the force diagram by means of a planimeter and was found to be the same for both engines, showing that the total amount of energy delivered by both is the same. This line is at the top of the shaded area and represents the *continuous* pressure necessary to carry a given load; now, when this necessary crank-pin pressure is exceeded in one part of a revolution, there must be a corresponding deficiency in another part. From Curve A it is seen that the turning pressure on the crank-pin of a tandem engine rises very greatly above the average amount twice in every revolution, and falls not only to zero, but becomes negative, due to the compression at the end of the stroke. The only practical way to try and smooth out the turning moment delivered by one of these engines is to use a heavy fly-wheel, which takes the excess energy represented by the area of one peak of the curve above the line of average pressure and caries it over to fill in the deficiency represented by the "valley" in the next portion of the curve. Of course, the larger the variation, the larger the fly-wheel will have to be, and where heavy fly-wheels are used, the wear on bearings is faster and more oil for lubrication necessary.

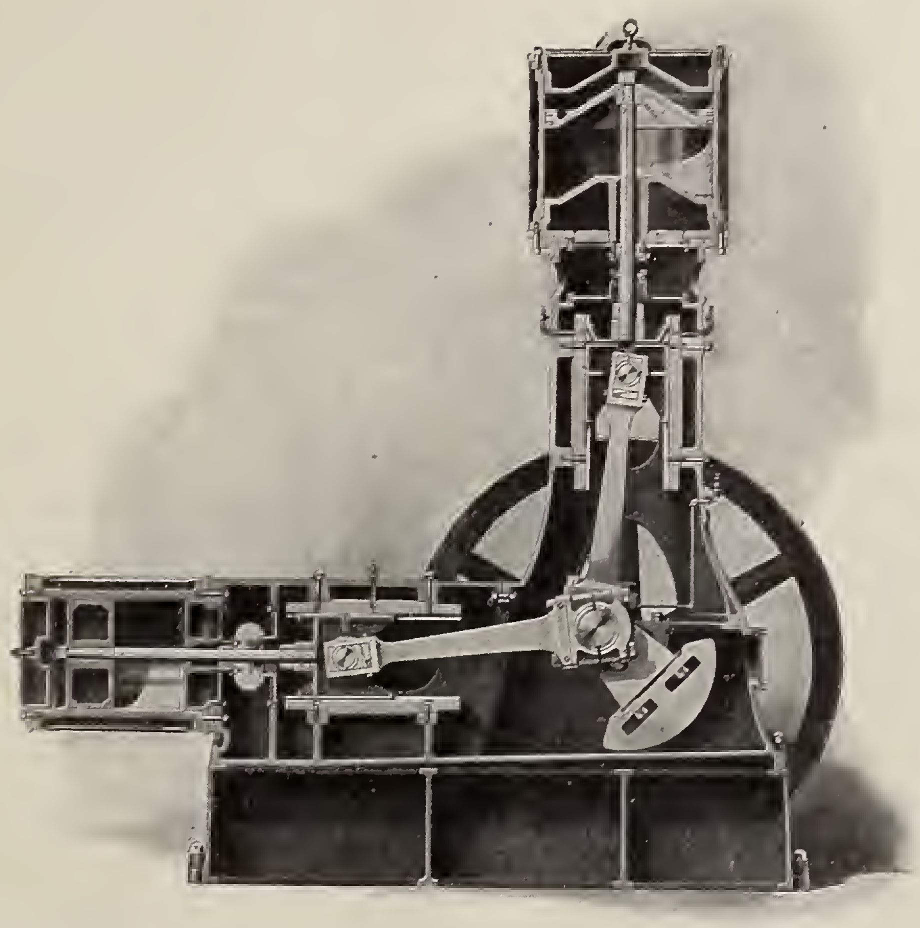
Another important point to be taken into consideration is the heavy reversal of stress which occurs near the end of the stroke in the tandem type when both pistons yank back at once. This tends to loosen bearings, both on the crank-pin and on the shaft, and in time developes "knocking." The much higher values of maximum pressure also necessitates heavier crank-pin and engine frames, as the parts of an engine always have to be designed for the greatest forces that they will have to withstand. Then again, when there are only two impulses per revolution they must necessarily be at least twice as strong as when there are four.

Uniform turning moment is very important where alternators are to be run in parallel, as the variation in angular velocity, such as occurs in

either simple or tandem-compound engines, sets up cross-currents which cause heating of the generator armatures and interfere with the regulation.

The American Engine Company has realized the special adaptability of this type of engine for small high-speed units, and have perfected designs and are now building units of from 100 to 500 h.p. to run at speeds of 250 to 325 r.p.m., and for condensing or non-condensing service. These engines are suitable for any class of service, but are especially adapted for isolated plant work, such as carrying hotel, apartment-house and office lighting loads. For this purpose their freedom from vibration especially recommends them. An ordinary lead pencil will stand balanced upright on one of these engines when it is running at 325 r.p.m.

It has been suggested that small turbines might be used for isolated plant work, but as has recently been pointed out, small turbines are not economical, especially when running non-condensing. In fact, small turbines consume 50 and 75 lb. of steam per h.p. hour when exhausting to the atmosphere; whereas one of the angle-compound engines, if supplied with steam at the same pressure, will furnish an h.p. hour on 25 lb. A small-sized turbine to be run as economically as this would have to exhaust to a high vacuum. This introduces the extra complication and expense of condensers and air-pumps, and leaves no exhaust steam available for heating, which is generally desirable in isolated plants.



CROSS-SECTION OF AMERICAN BALL ANGLE COMPOUND ENGINE SHOWING RELATIVE POSITIONS OF CYLINDERS AND OF COUNTERBALANCE WEIGHT

Western Electric-General Electric Agreement

The Western Electric Company has transferred its business of manufacturing electrical apparatus to the General Electric Company, and the manufacture of dynamos and motors for power-work has ceased at Hawthorn. The shops heretofore given over to this work are being dismantled and the machine tools formerly used in this work are being sold. The extensive space heretofore employed for this purpose is needed for the growing manufacture of telephone apparatus.

The Western Electric Company has reserved the right to manufacture such power apparatus as may be necessary for the complete equipment of telephone plants. This does not mean that the Western Electric Company has ceased to sell power apparatus; on the contrary, it will make redoubled efforts in this field. The apparatus to be sold hereafter by the Western Electric Company will be manufactured at the various works of the General Electric Company. All machines will carry the well-known "Hawthorn" name-plate. They will be made under the general supervision and specification of the Western Electric Company.

The agreement provides also for the transfer to the General Electric Company of patents, drawings, patterns, jigs and dies; and the shifting of this enormous business has been carried out with great smoothness and without inconvenience to the patrons of the Western Electric Company. It is a distinct triumph for their engineering and shop organization.

It is understood that the General Electric Company will continue to manufacture the Western Electric types of machines, and furnish repair parts for them until such time as a demand for them shall have ceased, and that as rapidly as possible the "Hawthorn" machines will be duplicates in design and characteristics of standard General Electric lines.

Intensified Arc Lamp

The intensified enclosed arc lamp marks a distinct advance in the field of interior illumination, incorporating as it does all the advantages of the enclosed arc lamp, together with numerous improvements. For years the enclosed arc lamp has been greatly in favor for general mercantile lighting in virtue of the whiteness of its light, low maintenance cost and high efficiency. By a radical change of design, the intensified arc lamp maintains these special points of superiority,

FIG. 1

even over the other improved artificial illuminants.

Two upper or positive carbons, 6 mm. in diameter and 305 mm. in length, are placed in converging tubes, so that the ends of the carbons are in contact. A self-acting weight bearing down on the top prevents one carbon from being consumed faster than the other.

One lower or negative carbon is used, 9½ mm. in diameter and 100 mm. in length. The lower carbon holder is movable in a vertical direction, being attached to a counterweight mechanism through which the action of gravity tends to hold it in

Fig. 2.

contact with the upper carbons. The magnets, acting through a clutch on a rod of the counterweight mechanism, draw the lower carbon downward, away from the upper ones. In this way the magnets cause the carbons to strike and maintain the arc, keeping the lower carbon floating at the point of electrical equilibrium.

When an arc is formed, the current density is much greater at the carbon tips than in the case of the standard enclosed lamp; and as the resultant heat cannot be readily dissipated, the carbon tips pass beyond the usual red-hot poker stage to the incandescent or white-hot stage.

In order to obtain the highest efficiency possible, a small diffuser is used, located directly above the arc. In this way a greater percentage of the light is distributed in the lower hemisphere. The resultant efficiency, therefore, is equal to about 1¼ watts per mean hemispherical candle-power at 5 amperes and 110 volts direct current.

The distribution of light is ideal for interior illumination, since maximum intensity is obtained in the working plane where most needed. Perhaps one of the most noticeable features of the lamp is the daylight effect created when in use. The light is of a soft, almost perfect white tone, and is steadily and evenly distributed. So pleasant and restful is the lighting produced, one is hardly conscious of the illuminaton.

At 5 ampers and 110 volts a carbon life of 75 to 100 hr. is obtained. This long life, together with the high efficiency, reduces the maintenance cost to a minimum, so that with the intensified arc lamp it is now possible to obtain the very best grade of illumination in large interiors at a minimum cost. The lamp, as manufactured by the General Electric Company, can be furnished for either direct or alternating current or multiple circuits.

Fig. 1 represents the intensified arc lamp equipped with ornamental casing. It will be noticed that this lamp differs materially from conventional designs and has verypleasing lines. The outer globe is made of leaded glass to correspond in effect with the casing. The lamp will therefore appeal particularly to dry-goods, clothing and department stores, as it fills a long-felt want for an illuminant which is attractive by day as well as by night, and at the same time which meets the requirements of high-grade illumination and minimum cost.

A Radical Improvement in Jet Condenser

The great impetus which the study of condenser problems has received during the past few years has resulted in the improvement of the surface condenser so that, whereas a heat transmission of 200 or 300 British thermal units per square foot of surface per hour per degree average difference of temperature was formerly considered acceptable, condensers are now built in which the rate of transmission has been raised to 900 British thermal units, and even more. The practical results of this are that with the same amount and temperature of circulating water correspondingly less condenser tube surface will be required, or with the same surface, less, or not so cold circulating water, to maintain the same vacuum.

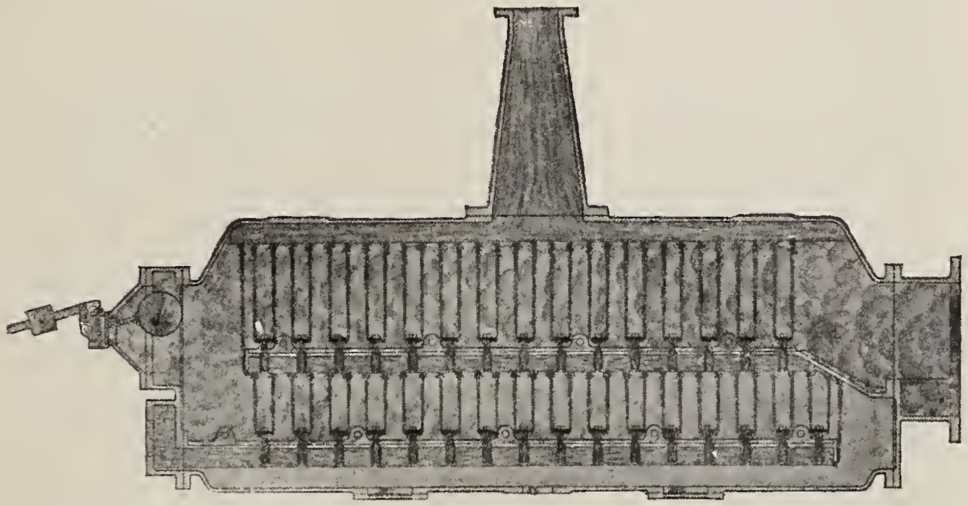
With the jet condenser it is not so much a question of improving the rate of heat transmission as of insuring thoroughness of intermixture —that is, of bringing each particle of water so intimately in contact with the steam that it will be heated to the steam temperature and its full capacity for absorbing heat realized. This is desirable in order that the amount of circulating water to be pumped and the power consumed in pumping it may be minimized, and in order that the water from the hot well may be more suitable for boiler feeding, since any loss of temperature therein increases the coal consumption at the rate of 1 per cent. of coal for each 10 degrees fahr. that the final temperature of the circulating water falls below the temperature corresponding to the vacuum. In other words, the hotter the water from the hot well, the less will be the steam required in the feed water heater, or the less the coal required under the boiler if no heater be used.

We illustrate herewith a new form of jet condenser recently installed in the powerhouse of an electric railway company by the Wheeler Condenser & Engineering Co., of Carteret, N. J. This outfit is installed in the basement beneath a Westinghouse-Parsons 1,000-kw. steam turbine. The injection water is taken from a creek nearby, and the warm water is pumped from the condener head by a centrifugal pump driven by a vertical engine. Air is withdrawn by a rotative dry vacuum pump, while a horizontal relief valve provides outlet to atmosphere in case of stoppage of circulating water.

The salient features of this condenser may be observed in the accompanying cross-sectional drawing which, however, does not show the exact type of hot well installed in the above plant. The condenser head, however, is identical. Referring to the drawing, the water is introduced at the upper right-hand corner into an extended trough or pan, from which it overflows through numerous short tubes, also at the edge on the extreme left, falling into a second and similar pan provided with similar overflow pipes and weir, and finally falling into the lower part of the shell, and overflowing thence to the barometric column or to the centrifugal or other type of pump serving to overcome the atmospheric pressure.

The steam enters through the opening at the left, passes horizontally across through the shower of water, ascends to the second level, passes to the left through the upper shower, and finally all that is left of the steam vapor, together with the air and other gases, passes horizontally to the right and over the entering and coldest water at the top to the dry vacuum pump suction opening in the upper-

most part of the shell. It will be noted that the cross-section of the passage traversed by the steam continuously diminishes as the volume of steam is reduced by condensation and that, therefore, a uniform, steady velocity is maintained throughout, leaving no dead pockets in which air might accumulate. Air is nearly twice as heavy as the same volume of steam at the same temperature, and unless swept forward positively will collect in the lowest part of the condenser shell. In surface condensers it is allowable to place the air pump suction at a low point, but not in jet condensers because of the possibility of water being carried over. In order to lessen the size and work of the air pump it is also important that the air may, at the last moment, be in contact with the coldest water.



LONGITUDINAL SECTION OF WHEELER COUNTERFLOW OR RAIN TYPE JET CONDENSER; STEAM ENTERS LOWER COMPARTMENT AT LEFT, WATER UPPER COMPARTMENT AT RIGHT

From the drawing it will be seen that it is impossible for any of the steam to pass to the air pump suction without having traversed all of the sprays. The water is finely divided by the small baffles hung below the tubes. In some of the older types of direct-contact condensers the "condenser cone" was substantially an open chamber in which the hot steam would naturally rise to the top, while the air would fall to the bottom, the very opposite of the condition sought, for if the air pump receives steam rather than air all its work is for nothing, while the air keeps on accumulating until the vacuum is seriously impaired.

At the right of the drawing will be seen a float controlling a vacuum-breaking valve. In case the water level should rise abnormally in the shell, due possibly to stoppage of the circulating pump, this will break the vacuum upon which the inflow of water will cease, since the circulating water is syphoned up to the condenser head from a lower level. The steam would thereupon escape through the relief valve.

Tests made on this condenser in actual service show that the innovations introduced by the designers have worked to good advantage. On the day of the test the barometer stood at 29.9 in., while the street railway load on the turbine varied from full load to 10 per cent. overload. Temperature readings were taken by thermometers placed in the exhaust pipe and in the hot well, while the vacuum readings were taken from a mercury column connected to the condenser.

Although due to the widely varying load on the turbine, it was necessary to set the injection valve to care for the maximum load likely to be carried, it will be noticed that the temperature of the tail water was kept very close to the temperature of the exhaust steam, although due to the coldness of the condensing water available, the rise in temperature of the injection water was quite large, and only a comparatively small amount of water was required, a condition unfavorable to close adjustment.

It may be of interest to calculate approximately the ratio of steam condensed to circulating water used. Taking the first set of readings, we find a vacuum of 28.55 in. of mercury. Subtracting this from 29.9, the barometric reading, leaves 1.35 in. of mercury steam pressure. According to Peabody's tables, this corresponds to a temperature of 88.5 degrees fahr., although the reading of the thermometer in the steam space at the same instant was 90 degrees fahr. The latent heat of steam at 88.5 is 1042 British thermal units. To cool the condensate from 66.5 degrees fahr. to 87 degrees fahr. the temperature of the outgoing condensate will give 1.5 heat units, or 1043.5 in all. The entering temperature of the circulating water is given as 44 degrees fahr. and the final temperature is 87 degrees fahr., between which limits each pound of water will absorb 43 heat units. Dividing 1043.5 by 43 we have 24.3 as the number of pounds of circulating water required to condense 1 lb. of steam.

As a matter of fact, the amount would be less than this, since not all of the exhaust is steam when it arrives at the condenser, some of it having already condensed in the turbine and in the exhaust pipe, due to work performed and to radiation. Suppose that 10 per cent. of the steam is water—that is, that the quality of the exhaust is 0.90. Taking 90 per cent. of 1042 we have 940, adding 1.5, makes 941.5, and dividing by 43 gives 21.9, as the ratio of the circulating water to steam.

RESULT OF TESTS.

Vacuum	Absolute Pressure Ins. Mer.	Corres. Temp. of Exh. Steam	Injection In	Injection Out	Difference in Temp. between Steam and Cir. Water
28.75″	1.15″	83.5°	44°	80°	3.5
28.75	1.15	83.5	44	81	2.5
28.65	1.25	85.5	44	80	5.5
28.55	1.35	88.5	44	87	1.5
28.75″	1.15″	83.5°	43°	79°	4.5
28.75	1.15	83.5	43	76	7.5
28.6	1.3	87.	43	82	5.0
28.6	1.3	87.	43	82	5.0
28.7	1.2	85.	43	88	3.0

A New Printing-Press Motor Controller

In no application of individual electric drive to industrial purposes is the desirability of a properly designed controller better exemplified than in printing. The requisites of a wide speed variation and an ability to bring the driving motor to a quick stop have necessitated a special design of controller for this industry. The General Electric Company has perfected a printing-press motor controller, known as CR-171, which should meet the demands of the most exacting service.

As will be observed, the control is obtained by means of a single handle which projects through a slot in the front of the case. All external wiring passes through a slot at the bottom.

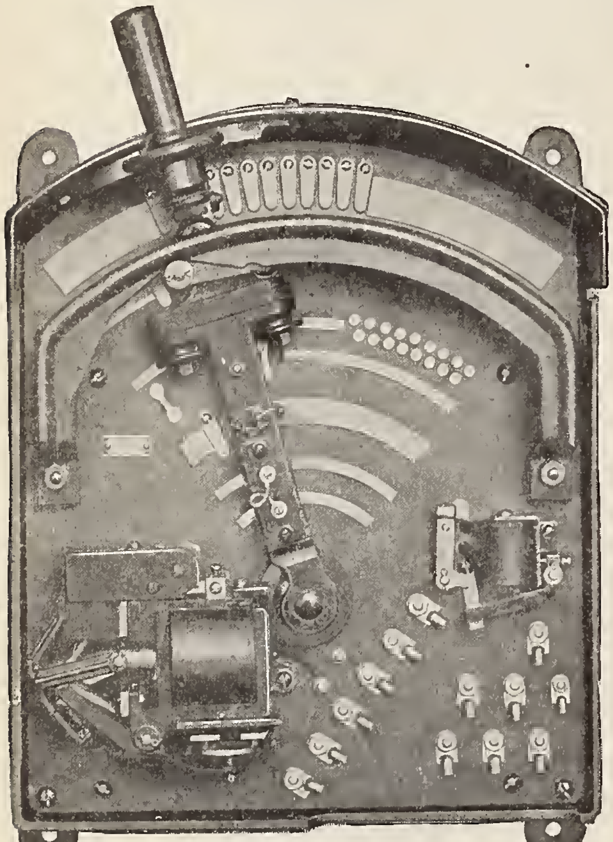
A range in motor speed of three to one is obtained by armature and field resistance. The operating handle will remain on any resistance point for forward running, but will automatically spring back to the "off" position from the reverse point.

A valuable feature of this controller is the use of a contactor for making and breaking all main circuits. The movement of the handle energizes the contactor and closes the motor circuit.

An overload device protects the motor from too rapid acceleration or an overload at any time. Should the contactor drop out, either by reason of an overload or failure of voltage, the operating lever must be returned to the "off" position before the contactor can again be energized.

A reliable and quick-acting braking effect is provided by means of a dynamic brake resistance, acting automatically when the motor circuit is broken.

A feature of especial value to the printing trade is the remote push-button control. A single push-button may be used to either start the motor or bring it to a quick stop from any



NEW GENERAL ELECTRIC PRINTING PRESS CONTROLLER

running position. This gives the operator perfect control when "setting up." Push-buttons may be installed at any number of convenient points.

The armature and brake resistances are contained in separate boxes, and are arranged for mounting on the wall or any other convenient place. The resistance is made up of single units which may be easily replaced.

A New Gas Pipe Ground Clamp

Among the recently approved devices announced by the Chicago Underwriters' Laboratories is the stamped steel ground clamp from the Sprague Electric Company, 527 West 34th Street, New York.

The clamp is made with two extension legs having screw centers 1½ in. apart, for attaching to an outlet box, and has a bolt and wing nut to secure the device to a gas pipe.

NEW CUTLER-HAMMER FACTORY

New Cutler-Hammer Factory

The importance attained by the Middle West as a manufacturing center is indicated by the increasing number of western concerns that have found it necessary to establish eastern factories. The latest of the more important concerns to do this is The Cutler-Hammer Mfg. Co., of Milwaukee, whose plant is the largest in the world devoted exclusively to the manufacture of electric controlling devices.

This company has just completed the erection of a new factory in New York City, the building being located in the Borough of Bronx, facing on Southern Boulevard, 144th Street and Timpson Place. It is five stories in height, contains about 100,000 sq. ft. of floor space and is of steel and brick construction throughout.

Electric current for light and power is furnished by the New York Edison Company, but provision is also made for an isolated, steam-driven electric plant in the basement of the building. The new factory also possesses a complete equipment for transforming the alternating-current furnished by the electric company into direct current, the latter being preferable for the operation of machine tools.

The building is equipped with a thoroughly modern sprinkler system, including roof storage tanks of 50,000-gallons capacity, and a 100-h.p. electrically operated centrifugal fire-pump with its 50,000-gallon cistern in addition. This, together with the substantial construction of the building itself, the excellent light afforded by reason of its location on three streets and the complete electrical equipment for light and power make the eastern plant of The Cutler-Hammer Mfg. Co. unquestionably one of the finest factory buildings in New York City.

The building in design and construction is the work of the Worden-Allen Co., of Milwaukee, whose success in construction work of this nature has led them to extend their operations to New York and Chicago, in both of which cities they have recently opened offices for the convenience of their clients.

We cheerfully publish the contribution on "Motor Drive," as it barefacedly violates almost every canon of trade-puffery and smacks strongly of midnight oil and ill-succeeding effort with the dictionary. It is the *handiwork* of a high-grade publicity bureau:

Motor Drive

"The development of a means for further increasing the usefulness of wall-paper trimmers has recently been successfully completed by the addition of a small electric motor to drive a modified form of the hand wall-paper trimmer manufactured by A. Allen & Company.

"This will be heralded with joy among the wall-paper trade, who have long felt this want. The construction is such that the operator has full control of the machine, being able to start and stop instantly, go slow or fast, the only effort required is a pressure of the foot.

"It will be readily seen that this is a great advantage over the old way of turning the crank, as it gives the operator free use of both hands. While the user can turn out double the work in the same time with the greatest ease, the cost for power is very small, as the Westinghouse motor used is but of ⅛ h.p.

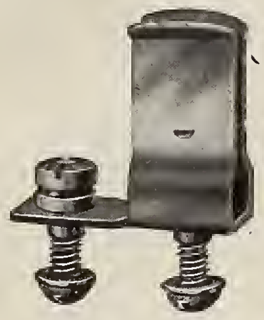
"It is but an exemplification of the fact that small motors are being util-

ized to drive all manner of machines formerly driven by hand or foot power, and in many instances are responsible for the developments of entirely new machines not possible without the motor.

"The outfit complete is sold by Messrs. A. Allen & Co., 2001-5 Carpenter Street, Philadelphia, Pa."

Trumbull Switches

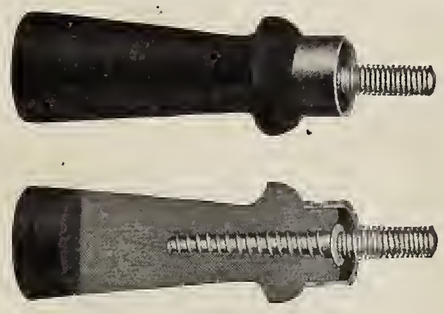
As illustrating the rapid development of switches, the line of manufacture by the Trumbull Electric Mfg. Co., Plainville, Conn., has been improved in 18 different details. Of the prominent changes we note the new foot piece on 15.50-ampere switches.



Foot Piece

The copper surrounding the holes is drawn down and acts as a dowel, fits firmly in the base and keeps the posts in alignment with the blades. By thus drawing down the copper 55 per cent. additional thread is given in the metal.

The new handles cannot work loose. By having the ferrule of heavy steel which extends over the tenon of the



New Handle

handle, the strain comes on the ferrule which will not crush and bears at every point, preventing the handle stud (or screw) from bending every time the handle is used.

The shoulder of the stud also acts as a stop and assures a uniformity in length of stud, also acts as a lockwasher, preventing screw from backing out of handle.

News Notes

Northern Engineering Works, builders of Northern Cranes, Detroit, Mich., have purchased additional land adjoining their plant, on which they are preparing to make extensions of their crane plant.

The receivership of Milliken Bros., Milliken, New York, has been terminated. Structural steel and galvanized steel towers for transmission-work comprise the chief line of manufacture of the Company, which is now under the management of Mr. Francis Oykes. Wm. Barclay Parsons is on the new directorate.

In a very attractive pamphlet entitled "The Dawn of a New Era" in Lighting, the General Electrical Company takes up the history of light from the tallow dip to the latest development in artificial lighting — namely, the tungsten lamp. Following the historical facts, the pamphlet is given up to the description of the tungsten lamp, its efficiency, cost of operation and various applications of the lamp in interior lighting. The comparison of cost of this with other illuminants is taken up in considerable detail. The pamphlet, which is numbered 3885, should be of interest to both the producer and consumer of current.

The Palmetto Phosphate Company, Tiger Bay, Fla., has recently put in operation its new producer gas electrical generating plant. The first of the three units was started November 23d, the second November 26th and the third December 2d. Briefly, the equipment consists of one 1100 h.p. gas-producer plant in three units, three 18 by 24 in. single tandem gas engines direct connected to 200 kw. 2300 volt generators, together with the necessary exciters, transformers, switchboards, etc. A large number of motor have also been installed, so that the entire plant is now electrically operated. Allis-Chalmers Company are the builders of the apparatus.

The Crocker-Wheeler Co. has recently sold to the Bethlehem Steel Co. 4800 h.p. of direct-current motors.

Personal

T. J. Mulvey, representative of the Bryan-Marsh Co. in New York State for the last eight years, has joined the active and hustling organization of the American Electric Lamp Co. as special representative. He carries with him the best wishes of his numerous friends.

Catalogue Notes

A little folder, No. 3884, recently issued by the General Electric Company, is interesting, in as much as it compares the tungsten and carbon sign lamps, and shows plainly the advantages to be derived by the use of the former.

Type IL in sizes from 1/6 to 20 h.p. and type ELC from 20 to 250 h.p., and known now as Hawthorn motors, are described in Bulletins 5131 and 5132, respectively, issued by the Western Electric Company.